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A TREATISE

ON

ARCHITECTURE AND BUILDING CONSTRUCTION

PREPARED FOR STUDENTS OF
THE INTERNATIONAL CORRESPONDENCE SCHOOLS
SCRANTON, PA.

Volume III

STAIR BUILDING, ORNAMENTAL IRONWORK ROOFING, SHEET-METAL WORK ELECTRIC-LIGHT WIRING AND BELLWORK

WITH PRACTICAL QUESTIONS AND EXAMPLES

First Edition

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STAIR BUILDING.

INTRODUCTION.

1. Stair building grew out of the necessity of securing an easy and safe passage from one level, or floor, to another. Such a passage might therefore be regarded in its inception as an inclined plane which connects two horizontal planes and provided with a series of equal risers, or steps, formed for the purpose of giving a sufficient footing to facilitate travel.

The construction of wooden stairways is considered the highest branch of joinery; more care and knowledge are required in their planning, more ingenuity in setting them out, and more skilful workmanship in their execution, than in any other work about a building.

The architect, in studying the plan and treatment of a stairway, should consider its adaptability for the building in which it is to be placed, its proposed situation, the weight likely to come upon it, the width to accommodate probable travel, and, especially, the ease of travel. It is not enough, as is sometimes done, to roughly calculate the treads and risers and sketch on the winders, leaving the stair builder to make the best he can of the conditions.

The first and most important consideration in designing stairways is their disposition for obtaining the utmost facility of access to the various stories to which they communicate. Care should be taken to secure proper headroom while ascending and descending, and the treads and risers should be arranged so as to secure easy travel. The proper width

of the stairway has also much to do with its appearance; in a private house, it should never be less than 2 feet 8 inches wide, and in public buildings never less than 4 feet 6 inches. The staircase wherein the stairway is enclosed should be given special attention, and the correct length and width should be carefully considered. It is not conducive to sound construction to be obliged to cut out trimmer beams; neither is it good practice to have to piece out a few inches when the staircase has been framed too large.

The importance of proper arrangement of stairways is evident, when it is considered that they are seen by every one, their convenience and beauty being readily appreciated, and their faults and defects instantly detected.

STAIRWAY CONSTRUCTION.

MATERIALS USED.

2. The materials most commonly used in the construction of stairways are stone, iron, and wood; the selection of material should be based on the location and the use to be made of the stairway. If placed outside of a building, stone, owing to its natural capability of resisting atmospheric influences, should be used; while, if placed inside a building designed to be fireproof, iron is generally selected, as it possesses great resistance to heat. Both iron and stone are preferable to wood when used in public buildings, where the amount of travel requires extra strength; wood, however, is the material most commonly used, especially in private buildings, where no heavy travel is to be expected.

TERMS USED IN STAIR BUILDING.

3. In stair building, a **riser** and **tread** together are termed a step, the *riser* being the upright portion which supports the *tread*, or horizontal part, upon which the foot is placed. The **nosing** is the projection of the tread beyond the face of the riser.

The term **run** is applied to the aggregate width of the treads.

Where the risers are parallel to each other on plan, thus forming straight steps, the steps are called **fliers**; but where the risers radiate on plan, forming triangular treads, the steps are called **winders.**

The term **flight** designates a succession of steps between one starting place and the one next above it. The spaces wider than steps, which constitute resting places between the flights, or which are the terminations of the stairways, are termed **landings,** or platforms. If the landing is square and occupies half the width of the stairway, it is called a **quarter-space** landing; but when it takes in the full width of the stairway, it is called a **half-space** landing. The space required for landings is sometimes filled in by winders; this is especially the case in geometrical stairways and those in which the run is limited. In every case, it is the quantity of space in the run that decides the nature of the landing, whether it is to be quarter or half space, or filled in with winders. Where the run is unlimited, a half-space landing should be adopted; but where the run does not allow this kind of landing, a quarter space is preferable to winders, as the latter should never be put in a stairway when they can be avoided.

The lower step of a flight sometimes has its outer end in the form of a horizontal spiral, and is then termed a **curtail** step. When the lower step is rounded to a semicircle, it is known as a **bull-nose** step. Where steps have an outward curve, they are called *swelled* steps; this form is generally used when the front stringer is curved out at the starting of the stairway.

If, in ascending a stairway, the hand rail is on the right-hand side, the stairway is called a **right-hand** stairway. If the hand rail is on the left-hand side, the stairway is called a **left-hand** stairway.

The above are some of the more common terms used in stair building; others will be explained as occasion arises for their use.

GENERAL CLASSIFICATION.

4. Stairways are known as dog leg, open newel, and geometrical. A **dog-leg** stairway has no well hole, and the face stringer of the upper flight is vertically over that of the lower one. A **well hole** is the space on plan between two flights when the stringers are not located in the same vertical plane. The objection to dog-leg stairways is that the hand rail is not continuous, but strikes the soffit of the upper flight.

Where newels are placed at the angles of the well hole, the stairway is termed an **open-newel** stairway; but when the stringer is continued in a curve perpendicular to the curve on the plan round the winders, the stringer is said to be **wreathed**, and the stairway is designated as **geometrical.**

5. The above classification relates more especially to the general design than to the structural details, many of which

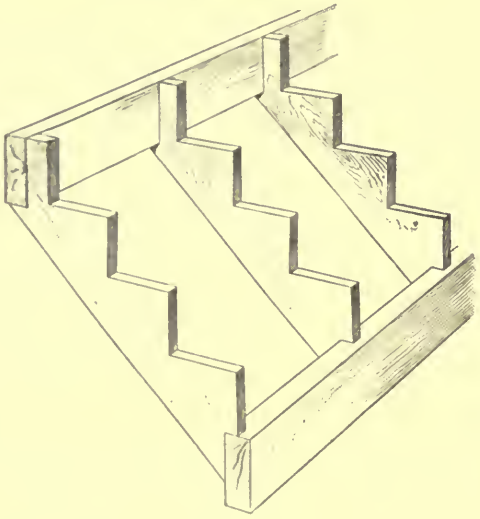


FIG. 1.

are common to each. When classified with relation to the methods of construction, there are two systems; the first consists in the use of rough timbers, or *carriages*, cut to the

angle of intersection between the treads and risers, as shown in Fig. 1; the other, which is the more generally used, has the treads and risers grooved, or *housed*, from $\frac{3}{8}$ to $\frac{1}{4}$ inch, into the prepared stringers. In the first case, the treads and risers are nailed on the carriages, and, where they intersect with the wall, a board of the same thickness as the baseboard connecting with the stairway is *scribed*, or cut, to the required outline so as to fit closely the angles of treads and risers; this runs the full length of the stairway, forming what is termed the **wall stringer.** In favor of this method of construction are its simplicity and strength. Against its adoption may be adduced the great difficulty of satisfactorily scribing the wall stringers, and even when this is successfully done, the stairway is likely, in time, through shrinkage and jarring, to show imperfections.

The **carriages,** also called **horses** and **springing trees,** for the second form of construction of stairways, are not cut

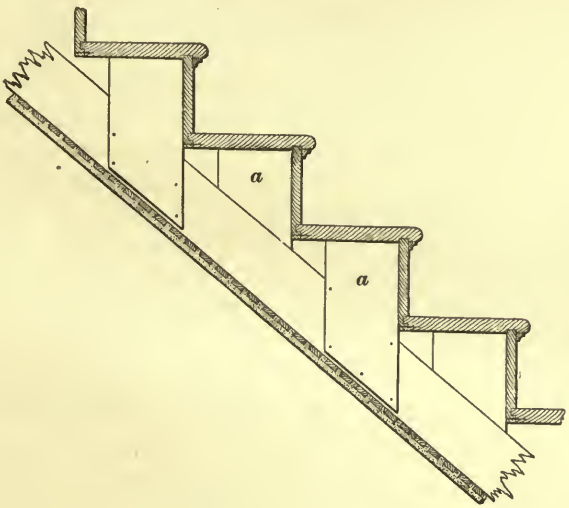


FIG. 2.

to the angle of treads and risers, as is the case in the first method, but are simply straight scantlings of sufficient

strength to support the stairway and its probable load, rough brackets being nailed on the sides of these scantlings and fitted tightly under each tread, as shown at *a*, Fig. 2. In some cases, where the treads and risers are enclosed in stringers, the wall stringer only is housed to receive the treads and risers, the front, or outer, stringer being cut square to receive the tread, and mitered to receive the riser. When thus prepared the front stringer is termed a **cut-and-mitered,** or **open,** stringer, the wall stringer being termed a **housed** stringer. Occasionally both wall and front stringers are housed, in which case the front stringer is said to be a **close** stringer. Geometrical stairways are seldom thus constructed, the method being mostly confined to dog-leg and open-newel stairways.

In geometrical stairways, the front stringer is cut and mitered so as to meet the conditions arising from the wreathed portion of the stringer and rail, which are assumed to stand perpendicular to each other and in the same vertical plane. The rail in this case is wholly supported by the balusters, instead of by the newel, and the cut-and-mitered stringer affords a substantial footing to the balusters, which are dovetailed, glued, and nailed to the ends of treads; the nosing and molding of the treads being returned their full width on the face of the stringer. Stairs thus constructed are said to have *nosed* and *mitered* moldings, and when brackets are placed along the front stringer below the nosing, the stairway is known as a **bracketed** stairway.

DETAILS OF CONSTRUCTION.

RISERS AND TREADS.

6. Height of Risers.—In setting out a stairway, the first consideration should be to ascertain the exact height between the floors, the height to be measured from the top of the floor below to the top of the floor above. For this

purpose, a rule or rod is sometimes used, termed a **story rod,** on which the whole number of risers is to be marked. Care should be used in determining the risers, with the view of constructing a stairway having steps of convenient height. Experience teaches that between 6 inches and 7 inches rise is the limit of easy stepping; therefore, the total height of the story rod should be divided by either one of these numbers, which will give the number of risers required. Having in this manner ascertained the number needed, divide it into the height of the story rod; the quotient will be the exact height of each riser.

7. Proportioning Treads and Risers.—The next step is to ascertain the width of the treads, not forgetting the rules of proportion between treads and risers, and always remembering that the number of treads in each flight is one less than the number of risers; this is owing to the landing being counted as one tread.

There are several rules for determining the proportion which should exist between tread and riser for regular stairways, and upon which depends not only the appearance of the stairway, but the ease with which it may be traveled.

Three rules will be given, of which the first is the simplest, and is generally preferred.

Rule I.—*Let the product of the tread and riser equal the number 66.*

For example, assume that the riser is six inches high, then the width of the tread will be $66 \div 6 = 11$ inches. In the same way, the width of tread may be assumed, and the height of the riser found.

Rule II.—*To any given height of riser in inches, add a number that will make the sum equal 12; double the number added, and the result will be the width of the tread in inches.*

For example, assume that the height of a riser is 7 inches; then $7 + 5 = 12$, and $5 \times 2 = 10$, the width of the tread in inches.

Rule III.—*Draw a right triangle, as shown in Fig. 3, with a base of 24 inches and altitude of 11 inches. Mark the width of tread from a on line a b, as a c; at c erect a perpendicular, cutting the hypotenuse at e. Then c e indicates the riser.*

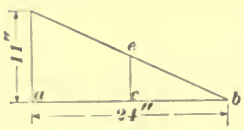


FIG. 3.

HEADROOM.

8. In trimming joists of staircases, the two cross trimmers which are called *headers* should be so placed as to allow sufficient headroom to meet all probable requirements of a stairway. The header (which determines the headroom) should be placed so as to secure 7 feet of headroom from the tread vertically beneath it. A careful drawing of the elevation of the stairway will accurately determine this point.

In cases where a number of winders are placed at the bottom of a stairway, and the risers thereby stand one above the other at the center from which they radiate, a considerable rise is produced at the commencement of the run, the amount depending on the number of winders. In such a case, the header is placed at the extreme end of the staircase, and thereby ceases to be a factor in the headroom. This applies especially to *boxed stairways*, which are enclosed between partitions.

Care should also be taken to make the staircase of the correct width, which should be at least 5 inches wider than the width of the stairway; that is, the distance from the center of the rail of the flight to the facia of the floor landing should be at least 5 inches, to permit the rail to pass clear of the nosing on the landing.

STRINGERS.

9. Laying Out.—A straight stringer is laid out by means of a *pitch board*, shown at (*a*) in Fig. 4. This board should be made of thin wood, with the grain parallel to the hypotenuse, so that the effects of shrinkage will be the least

possible. The base is cut to equal the tread, and the perpendicular to equal the riser. At (*b*) is shown the stringer, as marked out for the steps; the dotted line *a b* is drawn at a sufficient distance from the edge, so that the lower edges of the riser and tread will intersect on the line of the under side of the stringers, as shown at *d*. On the line *a b*, step off, with dividers, distance equal to the slope length of the pitch board. The latter may then be applied as shown, and its outline marked on the stringer edges. Templets, as

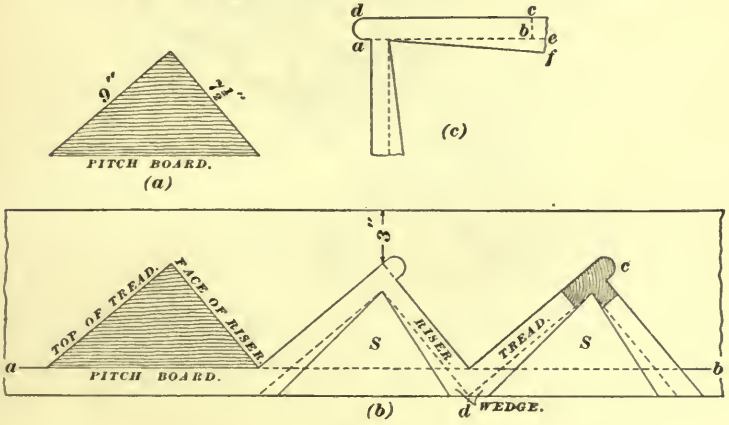


FIG. 4.

shown at (*c*), should be made for the treads and risers, care being taken that the pitch in both cases is alike, so that the same shaped wedges can be used. The lines *a d c b* show the section of the tread, and *a e f* shows the shape of the wedge. The tread and riser templets, when applied to the stringer, should have their outer edges coincide with the lines made from the pitch board, giving the outline shown at *S*.

To form the housing, holes are bored in the stringers adjacent to the nosing of the tread, as at *c*, and that portion is removed by means of a chisel. The lines of the templets may then be cut to the depth of the groove by a saw, and the material removed with a router plane.

Such a stringer is shown in Fig. 5, with the exception

that the under edge is kept somewhat lower than the point *a* in Fig. 4, and is preferable to the latter method in that the wedges are well supported at their outer ends. If the staircase will allow the insertion of the assembled parts, the

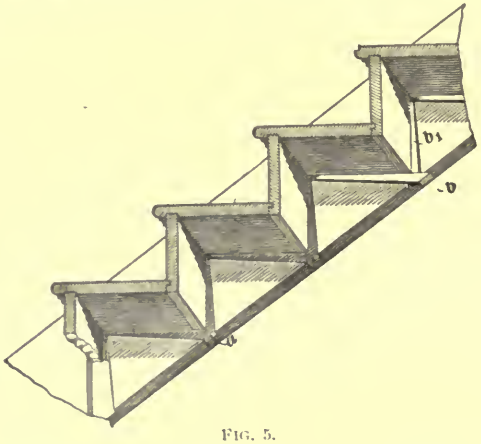


Fig. 5.

treads and risers are attached to the stringers, wedged, and glued into the housing, and the whole taken bodily to its place in the building. The wedges are shown in place at *b* and b_1, Fig. 5.

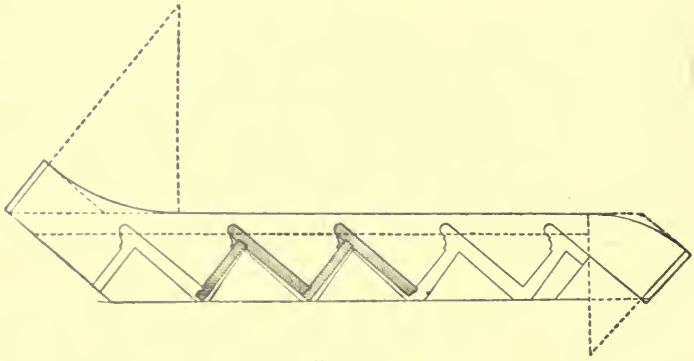


Fig. 6.

The wall stringer, as shown in Fig. 6, and also the front stringer, if a close one, are each grooved as already explained,

the depth depending upon the thickness of the stringer. Two or more carriage timbers are used in the width of the stairway, the number, depth, and thickness depending on the width of the stairway and the load to be carried.

The front stringer, as shown in Fig. 7, is well nailed to the front carriage timber *a*, while the other timbers are rough

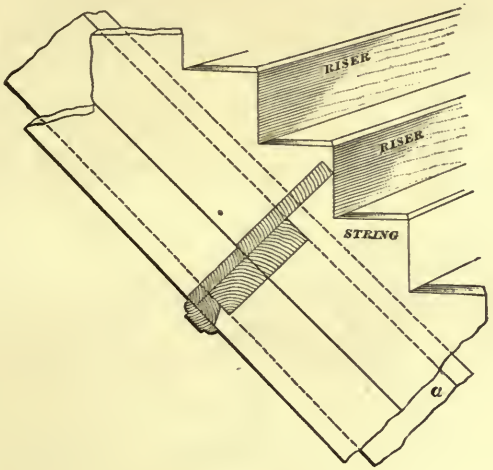


FIG. 7.

bracketed under each step alternately on the sides, and nailed as shown at *a*, Fig. 2. A furring strip is nailed to the wall in line with the lower edge of the carriage timbers, to receive the lath.

The prepared mortised wall stringer is nailed to the wall to square properly with the previously set carriage timber and front stringer.

10. Scribing Wall Stringers.—When the treads and risers are supported by rough cut carriages, it becomes necessary to cut a wall stringer that will fit around the steps and make a finish with the wall. In Fig. 8 is shown a method of *scribing* a wall stringer. The stringer is represented as being laid with one edge on the line of the nosings,

and the instrument to be used is shown in position. The hard-wood or iron bar *b h* has a hook on the lower end projecting sufficiently to enable the bar to clear the nosing when the point *b* is touching the face of the riser. The bar *b h* is placed against the guide *m* and loosely bound to it by the

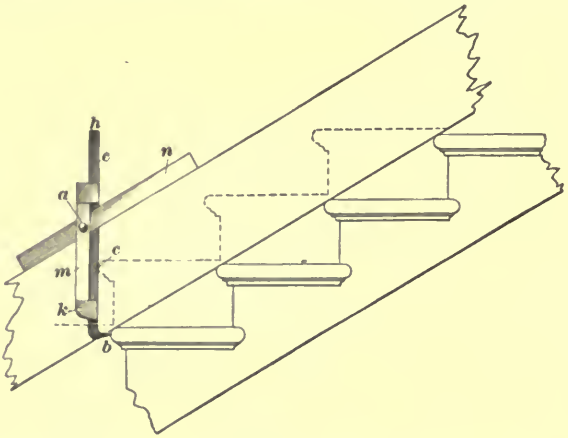


FIG. 8.

metal straps *e* and *k*. The strip *n* is fastened to *m* by a bolt *a*, which can be tightened so as to preserve the bevel. A small nick is made in the sliding bar *b h* at *c*, so that *b c* is the height of a riser. When the point *b* is on the end of the nosing, the nick *c* gives the position of the corresponding point on the wall stringer. Other points may be found in a similar manner, and the outline to which the wall stringer is to be cut can then be drawn.

CONSTRUCTION OF STEPS.

11. A portion of the upper edge of the riser may be tongued into a groove in the under side of the tread, as shown at *a* in (*a*), Fig. 9, instead of letting the whole thickness of the riser into the tread, as shown at (*b*). The lower edge of the riser may also be tongued into a groove in the upper

surface of the tread beneath it, as shown at *b* in (*a*), in which case the tread would have to be nailed up into the riser as at *c*; this method, however, does not give as good results as that shown at *a* in (*b*).

The finished treads and risers are glued, and clamped together with handscrews until the glue has set. From two to four well fitted blocks are then glued and nailed to the internal angle of the tread and riser, as shown at *b* in (*b*). In Fig. 9 (*b*) are also shown the dovetails for inserting the balusters.

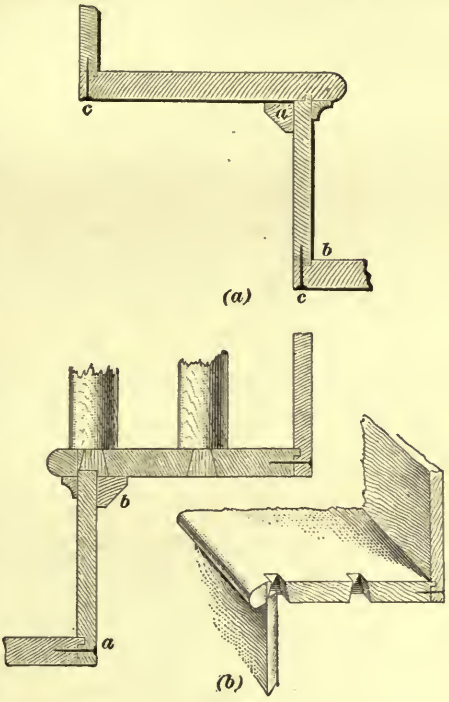


FIG. 9.

12. Bull-Nose Steps.—A form of step much used is represented in Fig. 10. The solid block is sawed into shape, and the riser is sawed out as shown, leaving a veneer for the face of the riser. The end *b* is firmly fastened to the solid block with screws. At *a*, a square hole is left the full depth of the riser, into which wedges are driven from each end, as suggested at *d*. The back of the veneer is covered with glue, and, as the wedges are driven home, it is clamped

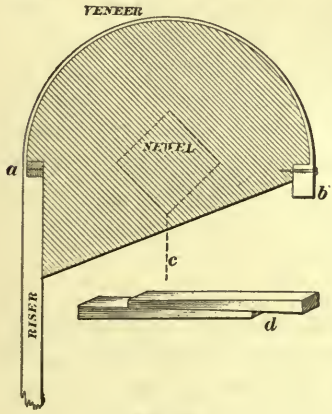


FIG. 10.

firmly against the face of the block. The newel is generally set on top of this step, as indicated by the dotted lines. The second riser may be placed in the middle of the newel, as indicated at *c*, or in any other position desired.

13. Curved Risers.—Where risers are curved, they should be made of solid wood, or of curved strips of seasoned wood glued solidly together. It is often difficult to get seasoned wood in pieces large enough to make a solid curved riser. In such cases it is desirable to bend pieces of 1-inch board by kerfing. Fig. 11 illustrates the method of finding the

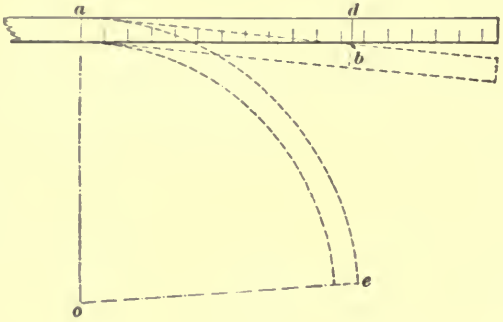


FIG. 11.

distance between kerfs for a curve of given radius. The method is as follows: Cut one kerf, as at *a*; then, marking the distance *a d* equal to the radius *a o*, bend the board to position *a b* until the saw kerf is closed, as shown. Measure the distance between *d* and *b*, or, in other words, the deflection of the board between *a* and *b*. This length *d b* is, therefore, the distance between kerfs, which, if continued, will shape the board to the curve *a c*. All the kerfs must be made with the same saw.

14. Platforms.—Where the stairways of a building are of considerable length, and are straight in plan, it is best to break the flight by a platform. Such a platform may be projected from the side wall, as shown in Fig. 12. In a

brick wall, the lookouts *a*, *a* should be set in at least 8 inches with slip keys tightly wedged between the bricks and the top of the timbers. The braces *b*, *b* should be well fitted

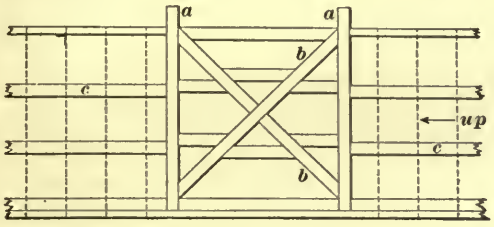


FIG. 12.

and spiked to the lookouts; these braces serve to keep the platform square and enable it to resist distortion by stress brought to bear on the carriage timbers *c*, and should be

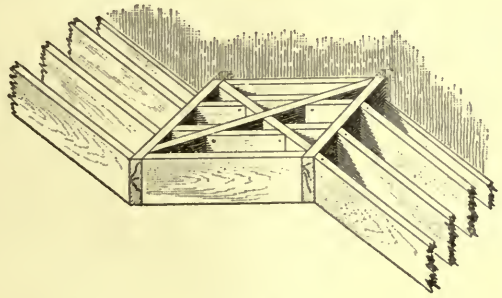


FIG. 13.

made of thoroughly seasoned wood. A flight terminating in a platform should not contain more than 12 steps. A perspective sketch of the platform is shown in Fig. 13.

CYLINDERS.

15. In geometrical stairways, the hand rail travels, unobstructed by newels, from the first step to the last, sometimes over six or more flights; it then becomes necessary to wreath the stringer and rail around the well holes. The

well holes thus treated are said to contain a **cylinder.** In stair building, any form of a curve constitutes a cylinder when used for this purpose. In a circular stairway, the cylinder assumed has a complete circumference of a circle for its plan, and the stringer and rail are made to wind around it, following a curve termed a *helix*—a curve of the same nature as the winding thread of an ordinary screw. The finished treatment of the stringer and balustrade is continued around the cylinder, and where the stairway terminates in a landing, the same treatment is continued along the trimmer beam. The portion on the beam corresponding to the stringer is called the *facia.* Thus it will be seen that the stringer of the flights, the cylinder of the well hole, and the facia of the trimmer beam are but parts of one continued stringer known by different terms.

Cylinders are built up as shown in Fig. 14. The construction shown at (*a*) is used for small cylinders, while for larger ones, the methods shown at (*b*) and (*c*) are used. The joints, as *s t* and *v z*, are glued and strengthened by screws or wooden dowel-pins. For extra fine work the face of the cylinder is veneered, so that the joints of the staves in the semicircle from *a* to *b*, in (*c*), are covered. The veneer is bent over a skeleton cylinder whose diameter is equal to the diameter of the well cylinder, and then backed with properly fitted staves, as *c* and *d*, well glued, and screwed or doweled at the joints, if necessary.

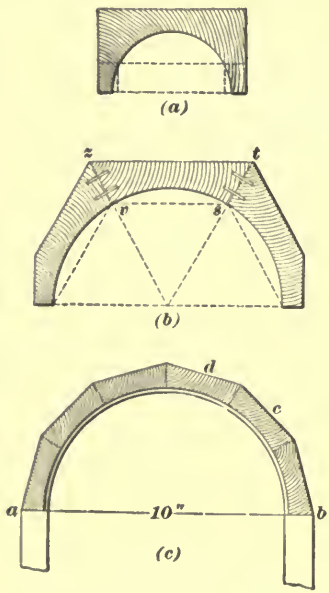


Fig. 14.

The end staves of small cylinders are fastened to the stringers in various ways. Two common methods are shown in Fig. 15. In the first method

(*a*), a dovetailed groove is cut in the stringer into which the end stave fits. Wedges *W*, glued in, hold the stave in place,

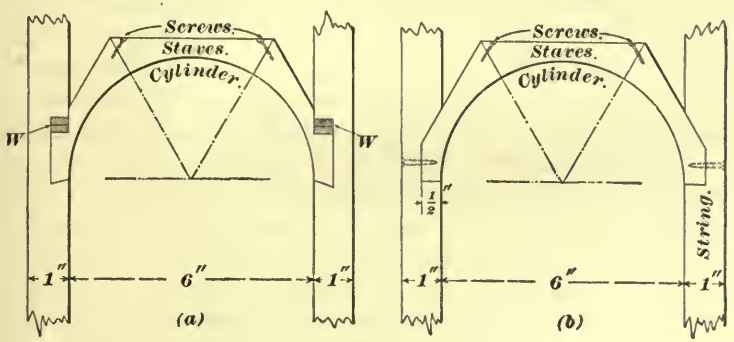


FIG. 15.

In the second method (*b*), the end staves are merely set into the stringers and screwed fast from the outside.

MISCELLANEOUS DETAILS.

16. Moldings.—All base and stringer moldings should be worked out of solid wood. Work that is to be bent is generally stronger when laminated, as shown in Fig. 16; but for moldings this method cannot always be used, since the joints will show, no matter how well the work is done. This is particularly true of hard woods. If the work is to be painted, however, this method is not objectionable.

FIG. 16.

17. Erection.—If the stairway is put up against the brown-mortared wall, the finished parts must be well covered with building paper, and rough boards placed over the paper on the treads, to remain until the interior woodwork is completed. The covering must be fixed in such a manner as to permit enough of it to be easily removed to allow the hand rail and balusters to be put up.

When the steps are set in place, they should be carefully inspected to ascertain if any of them are cut short and pieced, if any of the wedges are improperly glued, or the nailing of treads and risers omitted. When a person ascends or descends the stairway, it should make no creaking noise, as even a slight creaking is sure to grow louder in time and be a lasting reminder of defective work. Creaking is generally due to defective gluing, nailing, wedging, or to the use of unseasoned stuff in either the rough carriages or the finished material.

BALUSTRADES.

18. Newel posts, or **newels,** are used to support the hand rail, and are either made of solid materials and turned, or built up, box-like, in which case they are called *boxed newels.* They vary in design, form, and size, some—especially those placed at the bottom of the stairway, called the *starting* newel—often being elaborately decorated with panels and carvings.

The newel is also variously fixed in its relation to the steps adjoining. In ordinary cases it is placed on the floor, and when so placed its center should be in line with the center of the first riser. Where space is limited at the bottom of a stairway, the newel may be placed on top of the first step, and even on top of the second or third step; but in each case, it is desirable to place it so as to have the center of the riser at the newel center, and the steps outside rounded, and returned into the stringer; the end of the latter being inserted in a prepared mortise in the center of the newel.

The *angle* newels on the landings are generally smaller in size and have less decoration than the starting newels. The same rule applies to their relation to the risers; viz., that the center of the riser connecting should be at the center of the newel. Working from centers in stair-building construction is almost a maxim. The center of the rail is to be in the center of the newel; so, also, is the center of the stringer; and the center of the baluster is to be in the center

of both stringer and rail; and, as above mentioned, the center of the riser adjoining the newel is to be placed at the center of the latter.

19. **Balusters** are small columns, generally turned, set vertically on the ends of treads, forming an ornamental guard, and at the same time supporting the hand rail. When the front stringer is a closed, or housed, one, the balusters are fixed to the stringer, instead of to the treads, a grooved molding, called a *cap*, being prepared to receive them; the lower end of the balusters in this case are cut to the pitch of the stairway, and the top is either cut to the same pitch as the rail, or mortised into it. This applies to balusters having square ends. Frequently they are made square or round at the bottom, and turned to a spindle shape at the top, being then termed *pin balusters*. Balusters with square bases are preferable to those with round bases, as the square base gives bearing surface and resistance to movement almost double that of a round base. Holes are bored about an inch deep into the under side of the rail to receive the balusters, and the lower ends are either cut to the pitch of the stairway or dovetailed to the ends of the treads, depending on whether the stringer is housed or cut and mitered.

In ordinary stairways, two balusters are used to each tread, but in the better class of stairways, the number is increased, adding thereby to the beauty and strength of the balustrade, and general appearance of the stairway. With two balusters on a tread, they are placed half the width of a tread apart between centers, the short one standing close to the nosing and the long baluster being placed midway between the adjacent nosing balusters, so that it is exactly one-half the rise of the steps longer than the short one on the same tread. The usual height of pin balusters is either 2 feet 4 inches or 2 feet 8 inches, of which 1 inch is allowed at each end for insertion into rail and tread.

In extra fine stairways the space between the balusters is filled in with brackets of various designs, or the space is paneled; in either case the number of balusters is reduced

to one for each tread, ordinarily placed over the face of each riser, thus leaving the full width of the tread (less the thickness of one baluster) for the decorative brackets or panels.

20. Hand Rails.—The making of hand rails is a part of stair building which involves complex geometrical problems that belong properly to the stair builder. The architect, however, should see that the rail—except where placed over winders, whether at the bottom of the stairway or around the cylinder in the well hole—is set up parallel to the line of nosings. The pitch over the winders will be more inclined than it will be over the straight rail, and as the amount of the inclination determines the height of the rail, it follows that additional inclination over the winders requires more height for the wreath; but this addition in height should never be such as to cause an unsightly crippled appearance where the curve of the wreath intersects with the straight rail. The architect should also see that each baluster is vertical, and solidly glued and nailed to the hand rail, so that when tested, there should be no noise, which would indicate the presence of loose balusters through imperfect fitting, poor gluing, or carelessness in nailing.

Where the straight rail enters the newel without a ramp, it allows the newel to be made from 4 to 6 inches shorter than would otherwise be possible, the reduced height being often a matter of some consideration. Where such is not the case, the hand rail may be bent upwards (in which case it is said to be ramped), so as to enter the newel in a plane perpendicular to it, and the angle of intersection between the raised level portion and the inclined plane of the straight rail is gracefully eased. This last method is the one most commonly adopted, owing mainly to its superior ornamental characteristic.

21. Ramps and Easements.—In an open-newel stairway the rails usually meet the newels one above the other. To bring them to the same level, the rail must be ramped, and sometimes they are ramped and *kneed*—the latter being a concave easement with its upper end forming an angular knee.

When the knee is convex, the combined curve is then called a *swan neck* or sometimes a *goose neck*. The lower ends of rails abutting against the newels may be either straight or curved. When curved, the rail is said to be *cased*, and the curved portion of the rail is called the *easement*, and this arrangement requires the newel to be somewhat longer.

22. Stiffening Hand Rails.—Continued hand rails are sometimes provided with an iron brace extending across the cylinder from the facia to the bottom of the rail. Instead of

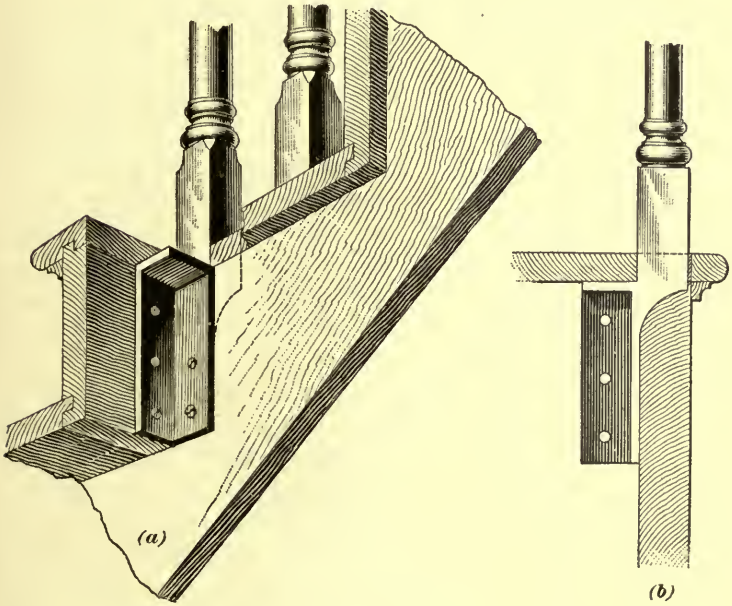


FIG. 17.

this brace, an iron baluster is often placed at each end of the wreath. Fig. 17 (*a*) is a perspective sketch of the base of such a baluster, which is formed into a flanged connection and attached to riser and stringer by screws. At (*b*) is shown a side elevation of the base, and its relative position with reference to the face stringer.

STAIRWAY DESIGN AND CONSTRUCTION.

ORDINARY FORMS.

23. Step Ladders.—One of the simplest forms of stairways in use is a step ladder, fixed or movable, such as is sometimes built from an attic floor to the roof, as is shown in Fig. 18, where (*a*) is a plan, and (*b*) an elevation. The top step should always have an increased width, and the sides of the ladder should be at least 6 inches wide by $1\frac{1}{8}$ inches thick. The steps are *gained* into the sides not less than $\frac{3}{8}$ inch and securely nailed or screwed thereto. This ladder rises 8 feet, or 96 inches, which, divided by 10, the number of steps, gives $9\frac{3}{5}$ inches for each riser. The run, or horizontal distance from the face of the beam at the landing to the bottom of the ladder, equals 3 feet 7 inches, less 3 inches for additional width of top step, leaving 3 feet 4 inches, or 40 inches, which, divided by 10, the number of treads, gives 4 inches as the width of each tread from a vertical line dropped from the nosing above.

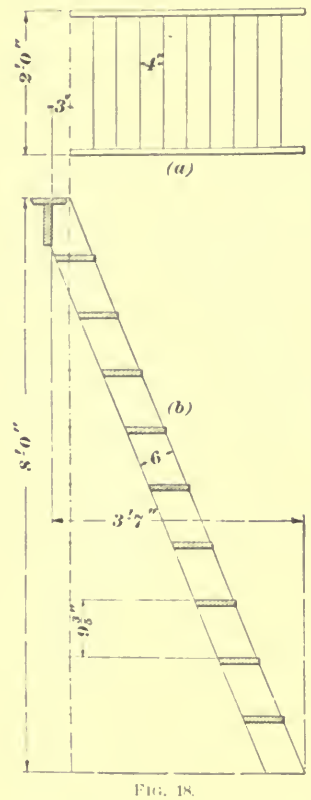


Fig. 18.

24. Plank Stairway.—In (*a*) and (*b*), Fig. 19, are shown the plan and elevation of a strong stairway, such as may be required for a shop or factory; *a* and *b* are newels, 6 inches

square, to which $4'' \times 1\frac{1}{2}''$ hand rails *c* and *d* are fastened and

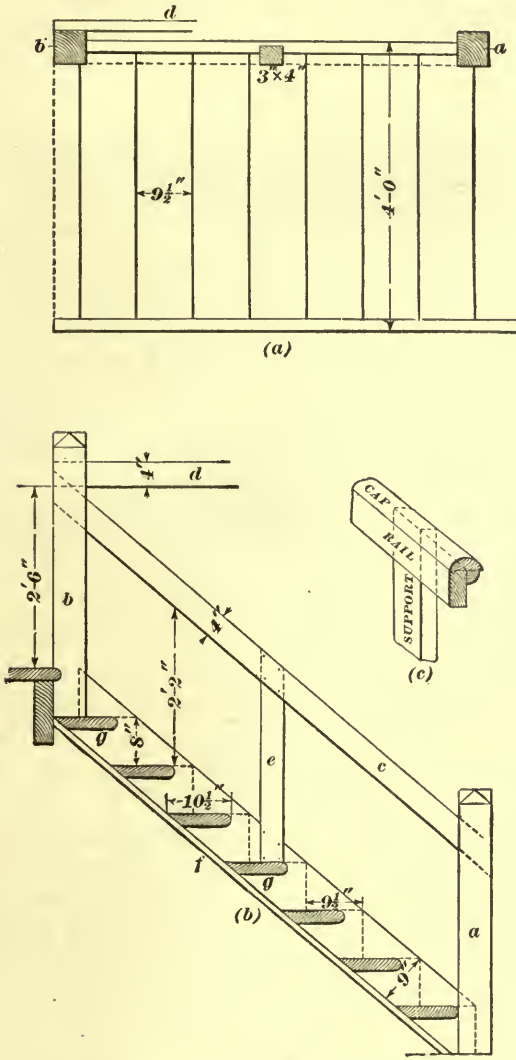


FIG. 19.

braced with one or more uprights *e*. At (*c*) is shown a section of the hand rail. Hard-wood treads *g*, 2 inches thick,

are mortised 1 inch into 3-inch timber stringers, tightly fitted into the mortises and well spiked, but not wedged. The soffit may be ceiled with matched lining, as at *f*.

GEOMETRICAL STAIRWAY.

25. Straight Stairway.—In Fig. 20 are shown the plan (*a*) and elevation (*b*) of a straight stairway with a 6-inch

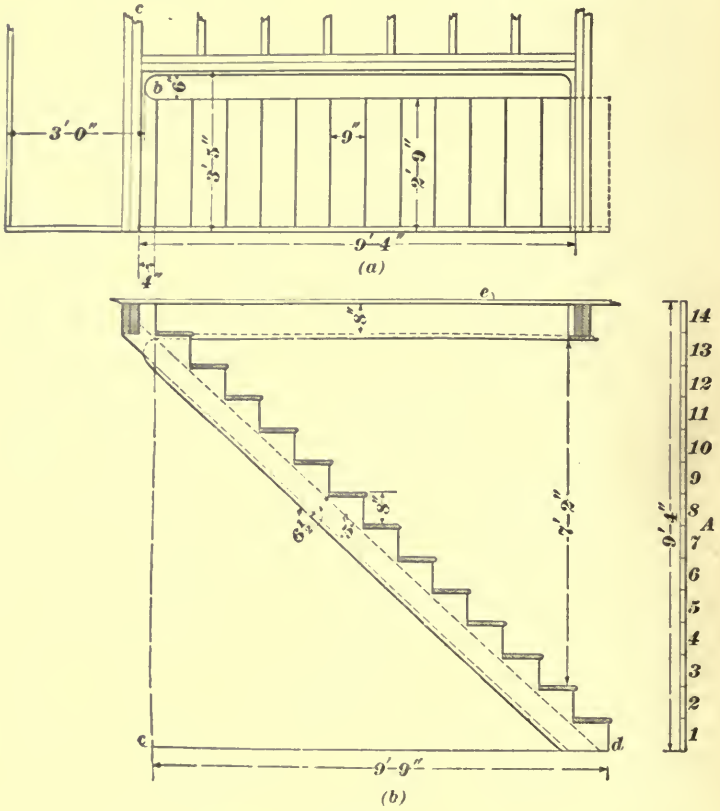


FIG. 20.

cylinder. The first requirement in planning this stairway is to fix the number and height of risers. The story rod *A* indicates the height of the story to be 9 feet 4 inches, or 112

inches, which, divided by 14, the number of risers, gives 8 inches as the height of each riser. The total run *c d* is 10 feet 1 inch, less 4 inches for the depth of the cylinder, which leaves 9 feet 9 inches to be divided into 13 treads, giving 9 inches as the width of each tread. As the floor at the landing makes one of the steps, there is one tread less than there are risers. The width of the stairway, shown in (*a*) as 2 feet 9 inches, is measured from the face of the plaster to the face of the front stringer, while the width of well hole includes the width of stairs, the diameter of the cylinder (in this case 6 inches), plus 1 inch for the thickness of the facia, and 1 inch for lath and plaster—altogether 3 feet 5 inches; and if the outside wall be constructed of brick, 1 inch more for thickness of furring will be required. At the landing of a straight flight, there must be at least as much room between the cylinder and the partition as the width of the stairway, preferably as much more as possible. In this case 3 feet is the width used in the platform, the 3 inches extra being allowed for convenience in moving furniture, etc.

The headroom of the stairway shown in Fig. 20 is 7 feet 2 inches from the top of the second step to the ceiling, and the point where this headroom can be secured governs the length of the well hole—as figured on the plan, 9 feet 4 inches. It is not necessary to make a drawing of the elevation in order to find the length of the well hole for the required headroom, as this can be calculated from the plan, by counting 12 risers down. If each riser is 8 inches, the 12 risers make 96 inches. From 96 inches subtract 10 inches, the depth of the floor, giving 7 feet 2 inches as the headroom. The 12 treads, of 9 inches each, make 9 feet, to which must be added 3 inches for the depth of the cylinder, and 1 inch for its thickness, making the total length of well hole 9 feet 4 inches.

The hand rail for such a stairway as this would be from 3 to 3½ inches wide, and the balusters from 1½ to 2 inches, square or turned.

26. Platform Stairways.—The plan (*a*) and the elevation (*b*) of a half-turn platform stairway, with a continued

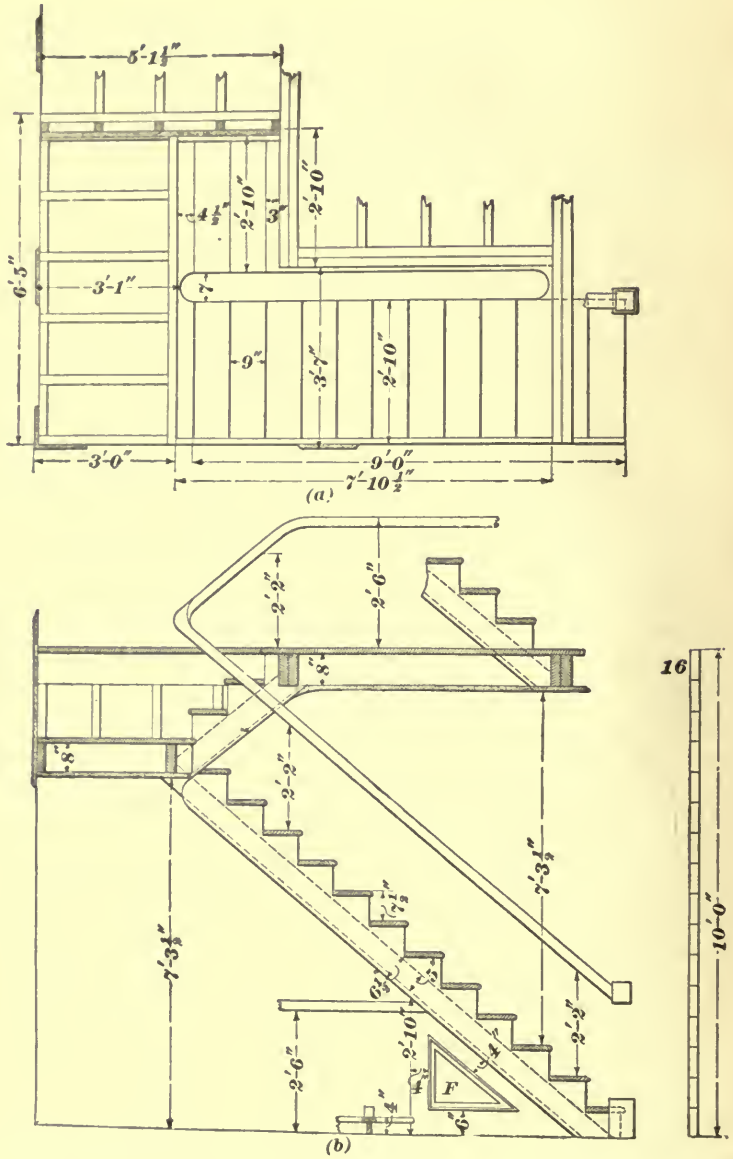
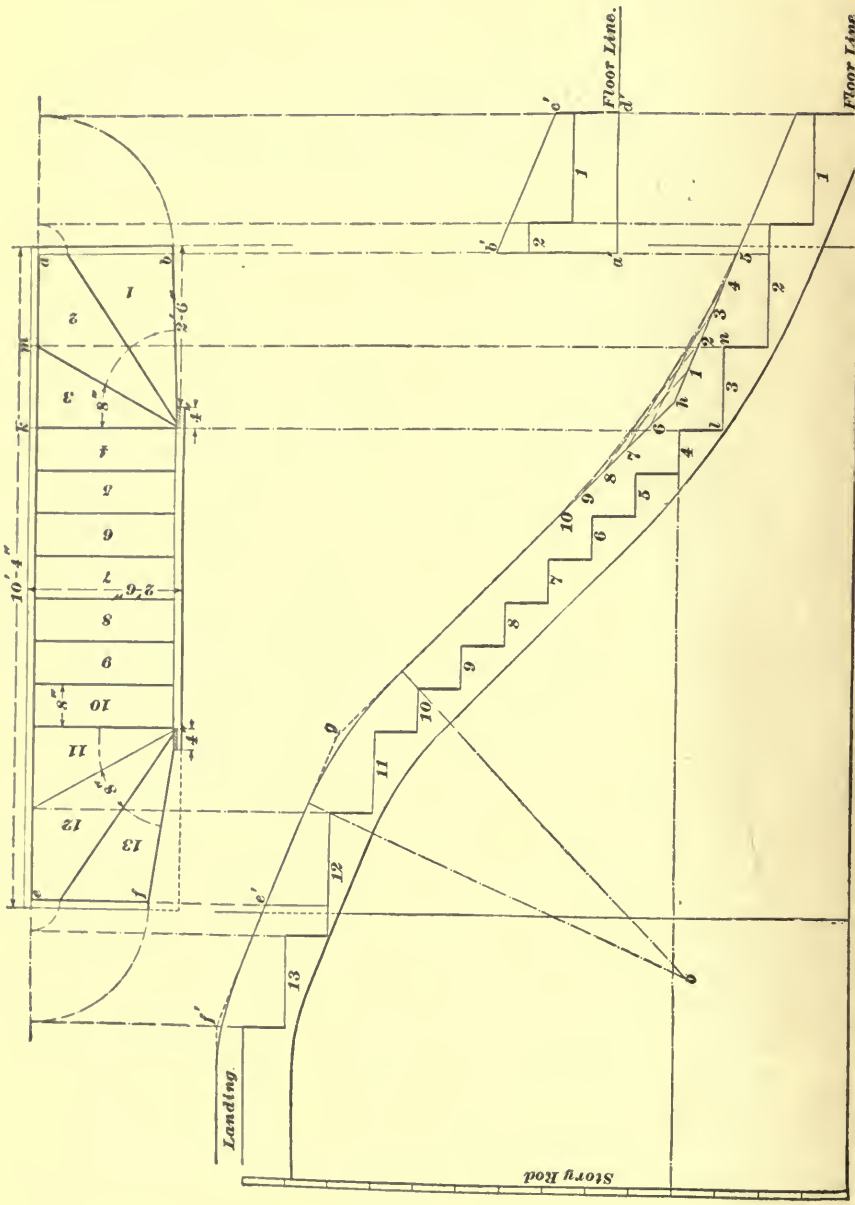

5'-1½"
6'-3"
4½"
2'-10"
3"
2'-10"
3'-1"
7"
9"
3'-7"
2'-10"
3'-0"
9'-0"
7'-10½"
(a)
2'-2"
2'-6"
8"
8"
2'-2"
7'-3½"
7'-3½"
7½"
6½"
5"
2'-10"
2'-6"
2'-6"
4"
F
6"
(b)
16
10'-0"

FIG. 21.

hand rail around a 7-inch cylinder, is shown in Fig. 21. This kind of a stairway is easy of ascent, breaking the flight, as it does, with a roomy platform, and allowing space for a window to light the stairway and hall from above the platform, while below it affords room for a doorway to the outside. With the last mentioned purpose in view, the soffit of the platform must not be less than 7 feet in height. The plan indicates also the timber framing of the well hole and platform. A jib panel *F* is shown at the start of the stairway in the elevation (*b*), the object of which is to close and neatly finish the angular space formed by the intersection of the stringer and the floor. The height of the jib panel is such as to receive the hand rail of the basement stairway. Where it is desired, the latter stairway may be enclosed by a paneled or lath-and-plaster partition extending up to the stringer of the upper flight.

The hand rail on the flight is 2 feet 2 inches in height from the center of the short baluster at the top of the step to the bottom of the rail; along the hallway the bottom of the rail is 2 feet 6 inches from the floor. These heights are based upon the commercial custom of turning ordinary pin balusters in lengths of 2 feet 4 inches and 2 feet 8 inches, 1 inch being allowed for entering the hand rail and 1 inch for the dovetail entering the tread, thus leaving the exposed part the length mentioned.

This kind of platform stairway can be altered in various ways, without changing the number of risers. For instance, a step can be taken from the upper flight, and added to the lower flight, increasing the run 9 inches and raising the platform one riser, making it 7 feet 11 inches. Then the well hole for the same headroom must be 9 inches longer, and the beam at the landing of the short flight must be brought forward the same distance. On the other hand, a step may be added to the short flight, making 4 risers in the short, and leaving 12 risers in the long flight. The well hole can now be shortened 9 inches, and have the same headroom as before; but it will be necessary to move the landing beam of the short flight back 9 inches, to accommodate the

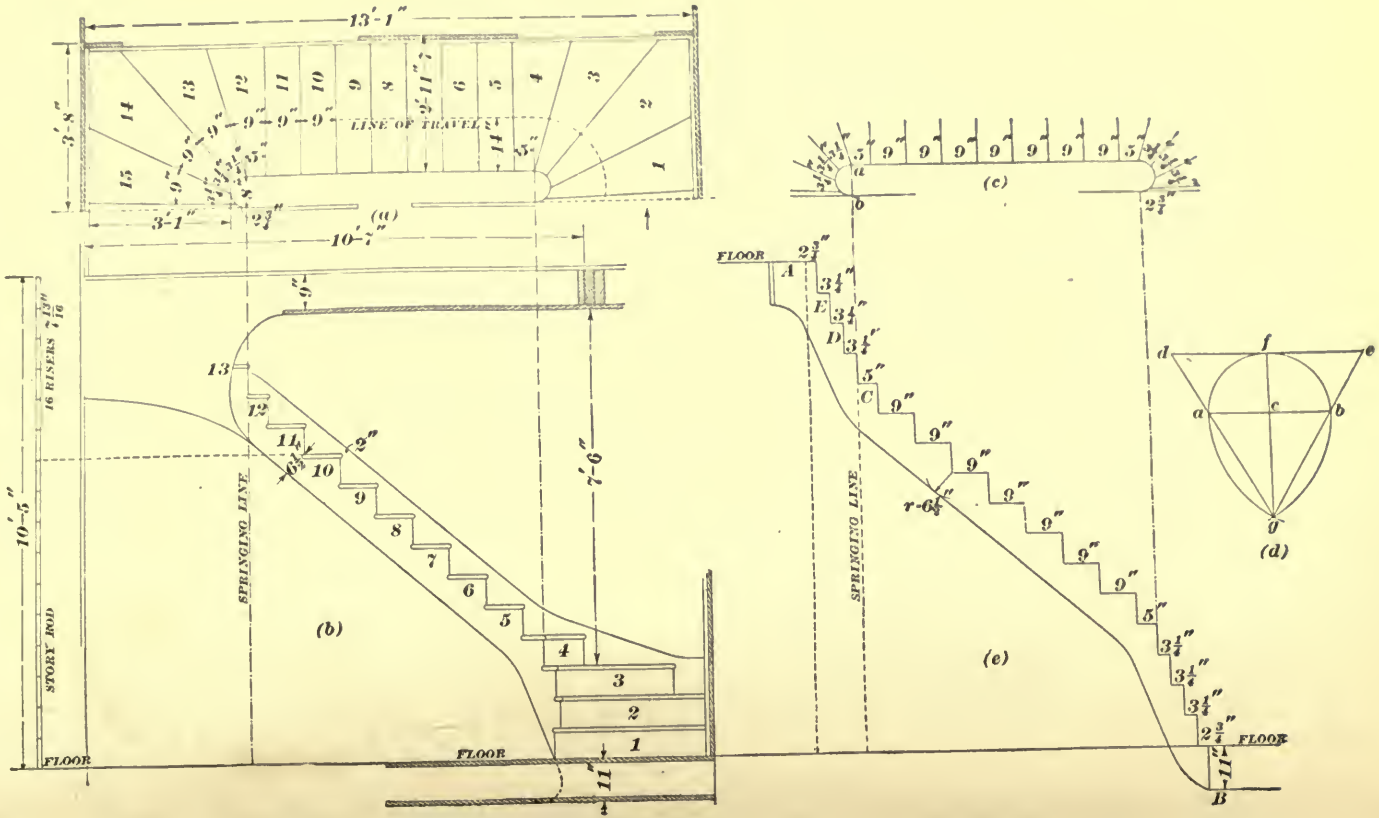

Floor Line.
Floor Line
Landing
Story Rod
10'-4"
2'-6"
2'-2"
8"
4"

additional step. The platform, however, is one riser lower, making it 6 feet 8 inches; but if the total depth of the platform can be made 6 inches, thus reducing its depth 4 inches, the height to the soffit of the platform will be 7 feet.

27. Winding Treads.—In Fig. 22 is shown an enclosed stairway, illustrating the method of laying out the wall stringer, easement curves, etc. The widths of the winding treads at the wall are projected down from the plan by lines *k l*, *m n*, etc. Then the wall stringer *a b*, at right angles to the main wall stringer *a e*, is revolved as shown, parallel to the main wall stringer and laid out in a similar manner; *a' b' c' d'* shows the stringer *a b* in elevation. The stringer *e f* is treated in a similar manner. The story rod is shown at the left, and the steps are projected from it and from the plan, as shown at step *4*. Where the treads are wide, as in steps *1*, *2*, and *3*, the line of the nosings makes an angle with the horizontal different from that made by the line of the nosings in the body of the stairway. This is because the uprights, or risers, remain the same, while the horizontals, or treads, vary in width.

28. Easement Curves.—At the angles, easement curves are necessary, or, at least, advisable. At *h* is shown a method of drawing an easement curve. From the vertex *h* lay off equal distances in both directions, as *1*, *2*, *3*, *4*, etc. Draw lines from *5* to *6*, *4* to *7*, etc. Through the points of intersection of these lines, draw a curved line by means of a spline. Otherwise, if the angle at *h* is sharp, perpendiculars may be drawn until they intersect, as at *o*; the curve can then be drawn with a compass.

29. Items of Detail.—Both wall and front stringers are to be mortised, or housed; for the steps, the treads and risers are to be glued together, wedged and back nailed, as before explained, in order to secure good, solid work. The front stringer has a vertical strip 4 inches wide spliced and glued to it so as to receive the winders. The well hole must be framed wide enough to include, beside the figured width of the stairway, the thickness of the enclosing lining.


13'-1"
3'-8"
LINE OF TRAVEL
3'-1"
10'-7"
(a)
10'-5"
16 RISERS 7 13/16"
STORY ROD
SPRINGING LINE
FLOOR
7'-6"
(b)
FLOOR
11"
(c)
SPRINGING LINE
(e)
FLOOR
B
d
f
e
a
c
b
0
(d)

30. Double Winders.—In Fig. 23 is shown a stairway winding one-quarter turn at the top and bottom, with an 8-inch cylinder, for a continued hand rail. In planning winding stairways, it is important to make the treads as nearly as possible of the same width on the line of travel. This line should be about 14 inches from the face of the stringer, as shown on the plan (*a*). The width between finished walls for this stairway should be at least 6 feet 4 inches, as follows:

Width of stairway from finished wall.....	2 feet 10 inches.
Diameter of cylinder	8 inches.
Hall passage.....	2 feet 10 inches.
	6 feet 4 inches.

The distance from the finished wall to the cylinder is made 3 feet 1 inch, so as to allow room for moving furniture. Where the stairway is continuous, the first and last risers of each flight should be placed 2 inches beyond the landing facia line, in order to make a proper finish with the facia.

In commencing the drawing, the starting and landing risers are marked on the plan, and the line of travel divided equally, as before mentioned. Then the space along the cylinder is divided; and lastly, the risers along the straight stringer are drawn in position. Lines are drawn through the points found along the line of travel and passing through the points located along the front stringer, thus completing the plan of the stairway. The elevation (*b*) of the stairway is drawn by projecting the lines of the risers down from the plan, and by drawing the lines of the treads horizontally from the story rod, as shown at tread *10*. For the development of the wall stringer, follow the method given in Fig. 22. The headroom, as shown, is 7 feet 6 inches from the top of the third step to the ceiling.

31. Width of Winders.—The winding treads must be made of uniform width around the cylinder, so as to obtain a uniform curve in the rail. It will be observed that there

is a 5-inch width introduced between the straight flight and the cylinder, which provides for a better easement, or ramp, from the pitch of the straight rail into the steeper pitch of the wreath rail; besides, if the winders were all contained in the cylinder, it would make a sudden and abrupt change of inclination in the stairway, causing travelers to stumble and fall.

32. Development of Stringers.—At (*c*) and (*e*) in Fig. 23 are shown the methods of developing the front stringer when each end curves around a cylinder. The plan (*c*) of the front stringer is the same as in (*a*). The distance *a b* in (*c*) is equal to the "layout" of the semicircular well, obtained as in (*d*), where *d e* is the *outstretched*, or developed, length of the curve *a f b*. The length of *d e* may be determined as follows: Make *a b* equal to the diameter of the cylinder; from *c*, with a radius equal to one-half of *a b*, describe an arc *a f b*; from *a* and *b* as centers, with a radius equal to *a b*, describe arcs intersecting in *g*. From *g*, through the points *a* and *b*, draw lines *g d* and *g e*; through *f* draw a line tangent to the arc and parallel to *a b*; the points where this line intersects with the lines drawn through *g*, will define the length of *d e*, or the developed length of the arc *a f b*. *A C B* in (*c*) is the front stringer, any outstretched step, as *C*, being obtained by projecting the line of the riser vertically from the plan, and the tread horizontally from the story rod. As the steps *D*, *E*, etc., in the cylinder, have their width marked on the plan as $3\frac{1}{4}$ inches, that width is therefore transferred to the development. The stringer in this case is $6\frac{1}{2}$ inches, measured from the angle between the treads and risers. This width is marked out with a compass from each angle, and a pleasing curve is drawn tangent to the arcs, as shown. When a cylinder is of this diameter, or smaller, at the bottom of the flight, the curve of the hand rail presents a better appearance, and is more convenient when the rail over the regular treads is continued on its pitch into the wreath, without ramping the straight rail. In this case there would

be an easement introduced between the straight rail and the wreath piece.

33. Arrangement of Winders.—In Fig. 24 are shown the plans of two different stairways brought together for comparison, each having one-quarter turn with an 8-inch cylinder and a continued hand rail. It will be seen that by the arrangement shown in (*b*) a platform is obtained, thus making the flight a much more desirable one. In plan (*a*)

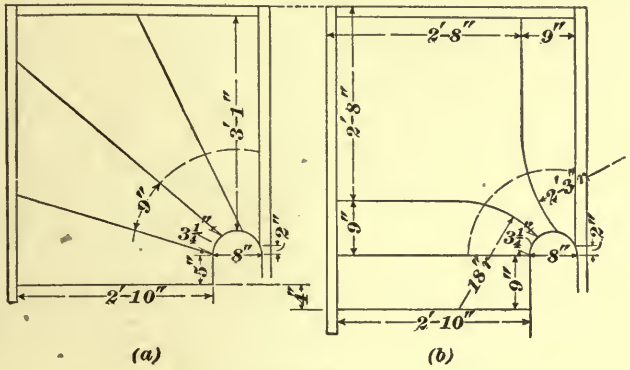


FIG. 24.

there are 4 winders, differing but little from the plan shown in Fig. 23; while in (*b*) there are 3 winders with slightly curved ends. The 5 risers so changed in their arrangement in (*b*) take 4 inches more run than the plan with winders as shown. The placing of the carriage timbers in such stairways is a matter requiring care, as the strength and stability of the stairway largely depend thereon.

34. Carriage Timbers.—In Fig. 25 is shown the plan of the top winders of a stairway similar to that in Fig. 23, *a*, *b*, and *c* being the principal timbers in position. The timber *a* is set in place after the stringers are put up, nailed to the floorbeam at *d*, and fastened to the wall at *e*. A piece of furring strip held in the direction *e d*, together with a straightedge tried along the line of the risers, will indicate the best position for this timber.

The bottom of the flight, as shown in Fig. 26 (*a*), may be timbered by securely placing a level piece *f k* extending from the front stringer into the wall, and then the two timbers *g h* and *l m* at a steeper pitch than the main timbers *n* and *o*. To do this may require the insertion across the well hole of the floorbeam *j i*; this is shown by the elevation at (*b*), where *l m* and *g h* of the plan are seen at, and lettered, *g' h'*, and *n* and *o* at *n'*. Or, instead of timbering in this manner, omit the level piece *k f* and place a diagonal timber

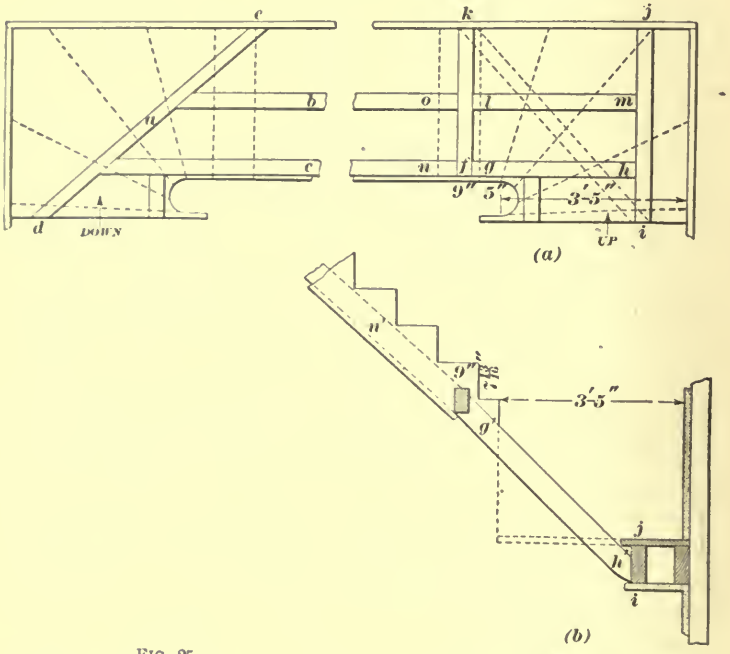


FIG. 25. FIG. 26.

i k, as at the top, and continue the principal timbers *n* and *o* to meet it. The remaining timbers are filled in as required for furring, which must be done so as to allow the lath to be nailed on in the direction of the risers. In order to obtain a smooth, curved surface on the soffit—which will be more or less warped—care must be taken to aline the blocking by means of a guide lath. In lathing so placed, care must be

taken that space has been allowed at all points, for the rivet of the plaster under stairways is subjected, at times, to heavy jarring which is likely to loosen the plaster unless it is well keyed or riveted.

NEWEL STAIRWAYS.

35. In Fig. 27 is shown a plan of a quarter-platform open-stringer stairway with 4-inch square newels framed in the angles, the handrails making straight connections with

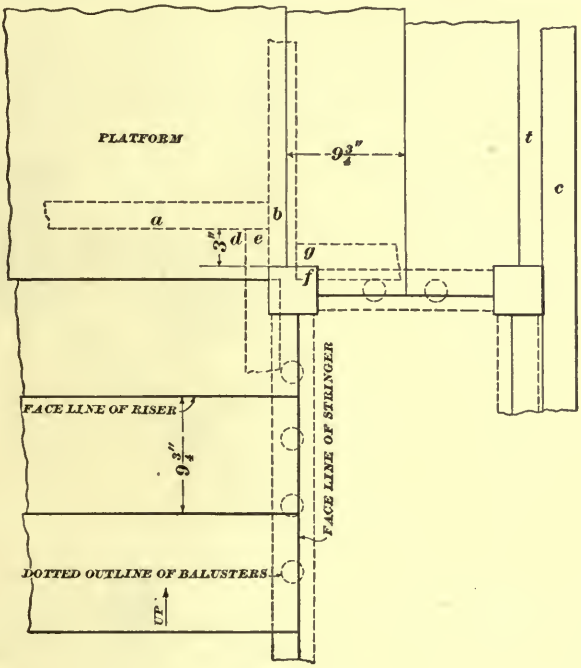


FIG. 27.

the newels, as shown in Fig. 28. The position of the platform beams *a* and *b* and of floorbeam *c* at the landing must be such that a good bearing is secured for the carriage timbers at *d*, *e* and *f*, *g*. The platform beam *b* must be brought forward to give a support of about $\frac{3}{4}$ inch for the newel. The elevation, shown in Fig. 28, is projected from the plan,

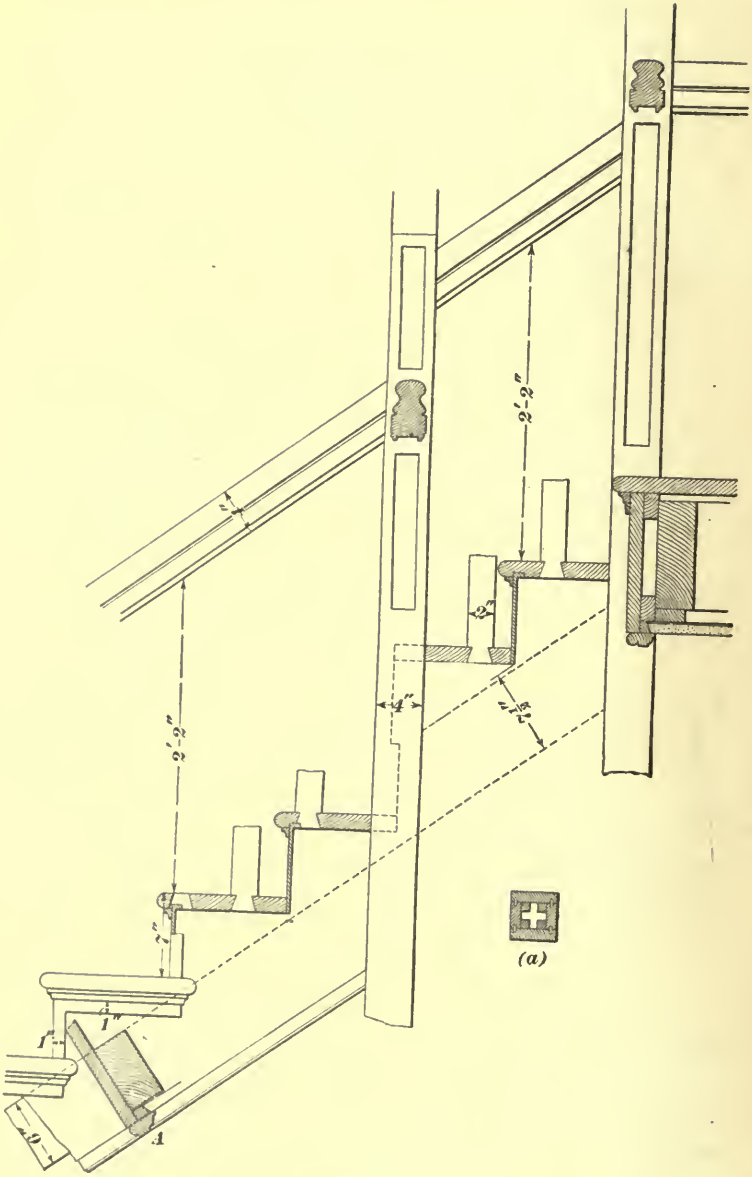


FIG. 28.

and shows the relative position of the newels, hand rails, balusters, and step trim; the latter is composed of $1'' \times \frac{1}{4}''$ fillets, nosing, and scotia. The newels are built up as shown at (*a*) in Fig. 28, slip-tongues being inserted into grooves in the sides, and the whole being properly glued and blocked. The blocks are glued first to the two narrow sides of the newel and when dry are planed square with the edge of these pieces. The whole is then heated in the hot box, and blocks, edges, and slip-tongues are glued and brought together with handscrews.

36. Open Stringers.—In Fig. 29 are shown an elevation and section of an open stringer, where fillets are used. At (*a*) is a portion of the stringer showing the step trim with fillets *a*, *a*; the lower portion of the stringer is relieved to

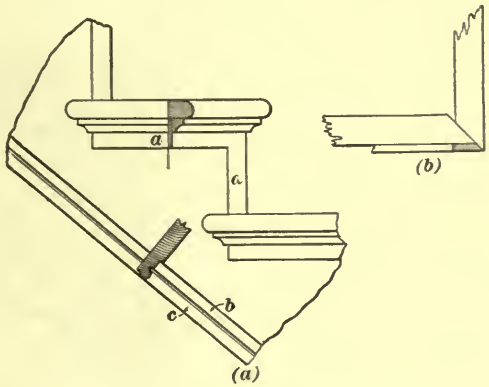


FIG. 29.

form a facia *b*, and the edge is formed into a quirk bead, against which the plaster would finish. This method, although often used, does not give as good a bond for the plaster as does the soffit mold shown at *A* in Fig. 28, in which the edge of the stringer is kept square. At (*b*), Fig. 29, is represented a section of the fillet, mitering with the riser, which shows that the face stringer requires to be kept back the thickness of the fillet, in order that the latter may miter properly with the riser.

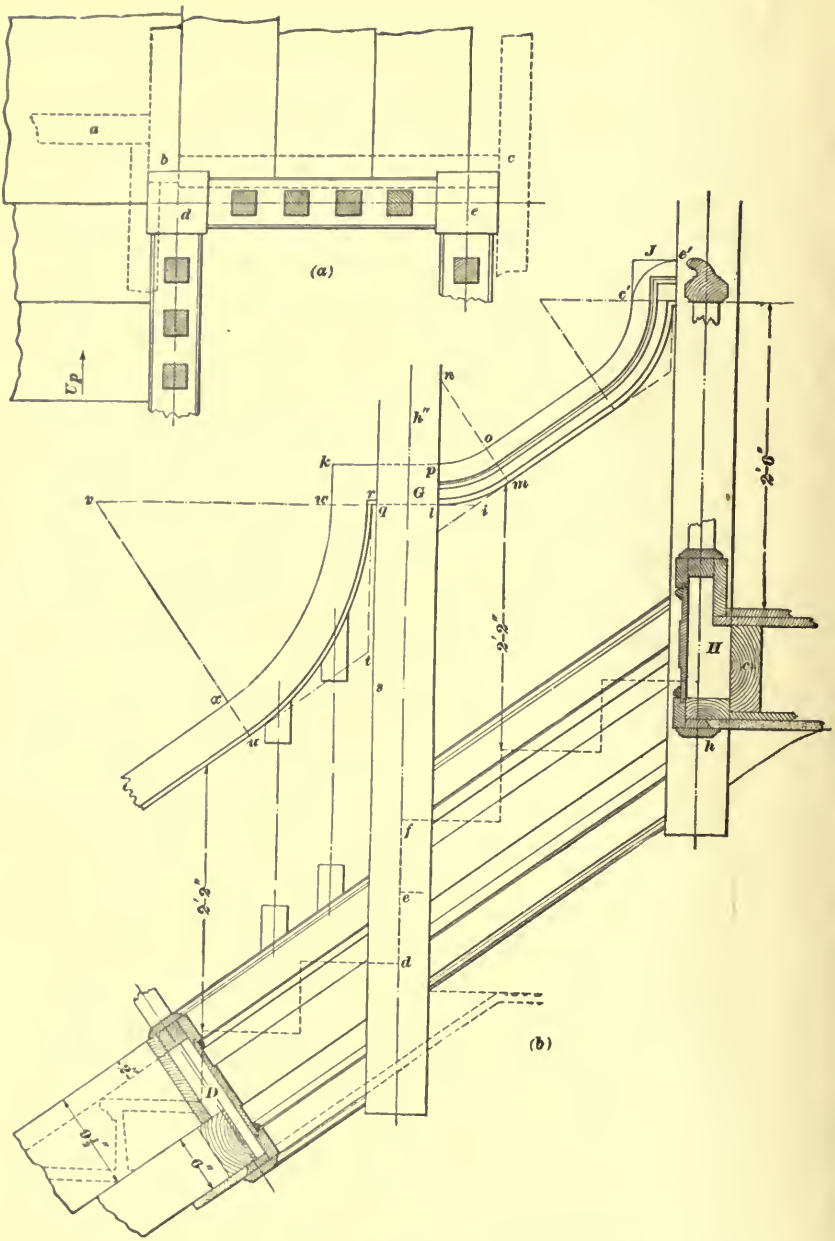


FIG. 30.

37. Close Stringers.—In Fig. 30 are shown a plan (*a*) and an elevation (*b*) of a quarter-platform stairway with 4 risers in the flight adjacent to the landing, close paneled and molded stringers, 6-inch square newels, 2½-inch turned and square base balusters, and a $4'' \times 4\frac{1}{2}''$ double molded hand rail, with ramp and knee, or *goose neck*, connection with newels. In the plan, *a* and *b* are the principal floor-beams of the platform, and *c* is the top landing floor-beam. In drawing the elevation, the first step is to locate the treads and risers as shown by dotted lines. The balusters may be placed at any distance apart that is desirable on close stringers, as their relation to the treads is not noticed. On the plan is shown their relation with reference to the newels from which measurements should be taken.

Observe, in the elevation of the lower newel, that there are two risers at right angles to each other at the center of the newel, one riser being from the top step of the lower flight to the platform, and one riser from the platform to the first step of the short flight, as shown at *d e f*. In this elevation the portion *d h e' h''* is the elevation, or side view, of the short flight, from *d* to *e* on the plan (*a*). A cross-section of the close stringer, showing the panel, timbers, blocking, etc., is shown at *D*, and from this the connections with the newels are lined in as indicated. The section *H* along the floor level is the same as at *D*, but if this should prove at any time to be too high above the floor, the panels may be reduced in width. Panel work of this character may have stiles at newel connections, and muntins at suitable intervals in the long flights and landing facias.

38. Half Newels.—In neweled stairways, the hand rails should always finish against a half newel at the wall connection, and the ends of the half newels may be shown below the soffit. Where half newels are placed on the walls opposite the platform newels, ornamental flat-arched spandrels may be framed between each

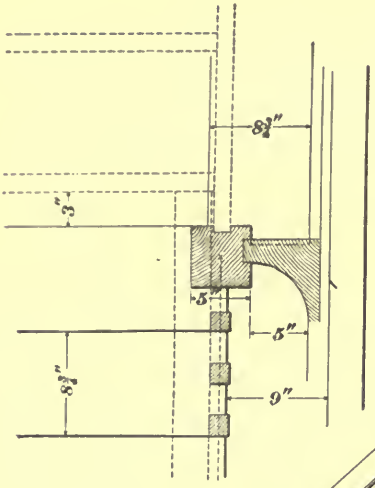


FIG. 31.

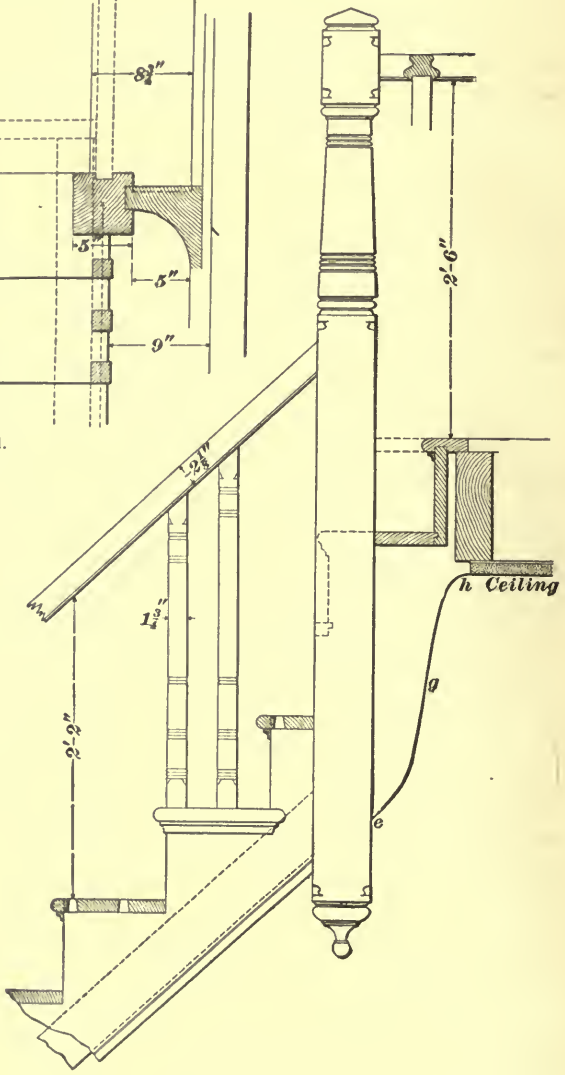


FIG. 32.

newel and half newel, thus finishing the soffit of the platform.

39. Newel Posts and Rails.—The length of newel posts is governed by the depth of the stringer, including the soffit molding. Fixing the height of the easement at *G*, Fig. 30, and the height of the level hand rail at *J*, the height of the hand rail up the flight is figured, and the rail is made parallel to the line of the stringer. There is nothing important in the position of *G*, except that it fixes the level of the knee at *k*.

To produce a good easement, *i l* must equal *i m*, and *m n* must be at right angles with *m i*. Let *m o* equal the thickness of the hand rail; from *n* as a center, describe the easement lines *o p* and *m l*. For the ramp and knee, make *q r* from $\frac{1}{2}$ to $1\frac{1}{2}$ inches; perpendicular to *q s*, draw *r v*; make *t u* equal to *r t*; from *u* draw *u v* at right angles to *t u*; make *r w* equal to the thickness of the rail, and draw *w k* parallel to *q s*. With *v*, the intersection of *r v* and *u v*, as a center, describe the arcs *r u* and *w x*. The ramp and knee at the upper landing are defined in the same way. The rail may be curved, as indicated by the arc *c' e'*, forming a *goose neck*.

40. Special Arrangement of Newels.—In Figs. 31 and 32 are shown the plan and elevation of a quarter-platform stairway having a quarter-cylinder connection to the landing, thus avoiding the use of a second newel.

41. In Fig. 33 are shown the plan (*a*) and elevation (*b*) of a straight stairway, with a single newel set diagonally at the landing, the stringer facia and hand rail being curved to enter two adjacent faces of the newel. In the plan, *a b c d* is the position of the carriage timber; *A* and *B* indicate the position of the floorbeams. Half balusters are set against the sides of the newel to which the hand rails are connected. In the elevation, *a' b' c' d'* show the depth and position of the carriage timbers, and *A* is the landing floorbeam. Draw *s' e' h'* in the elevation equal to the arc *o e h* on the plan;

through h' and c' erect perpendiculars for the sides of the newel; through c' draw $c'j$ parallel to the face of the newel; lay off $s''t'$ equal to st in the plan; parallel to $s''j$ draw $t'i$;

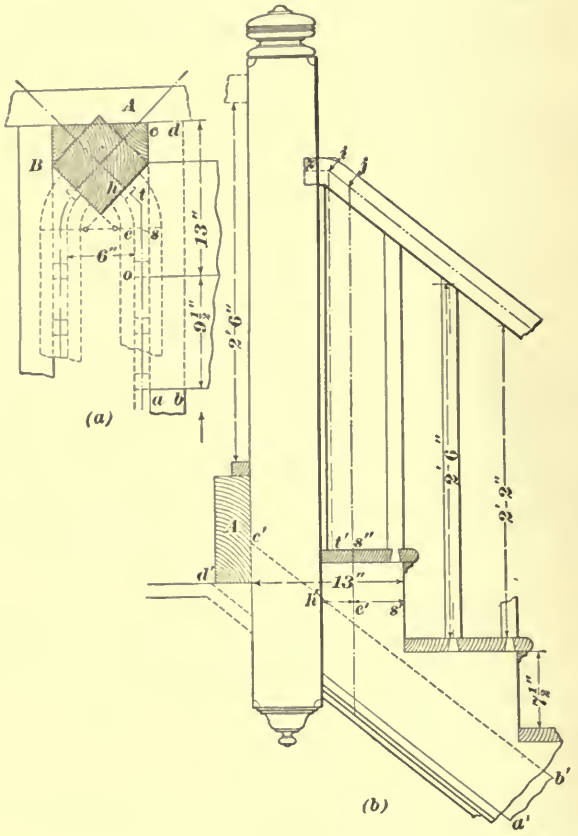


FIG. 33.

draw iz parallel to the tread, then jiz is the center line of the rail. This fixes the height of the flight rail at the newel; the level rail is 2 ft. 6 in. above the floor.

42. Swelled Steps and Curved Stringers.—It is very desirable to give a stairway a pleasing appearance at its

start; with that end in view, the stairway is often widened adjacent to the newel by curving out the front stringer 6 inches or more, and increasing the width of several of the treads by gracefully curving the riser. In Fig. 34 is shown a plan of the first three steps of a stairway treated as suggested. On this plan the elevations of 3 of the risers and treads are projected in order to show the connection of the rail with the newel. Draw the bottom line of the rail through the points where the centers of the short balusters would occur, as at *d d'*; set off from *dd'* the thickness of the rail, 2 inches, and draw the center line of the rail *e f*. The tangents *c b* and *c a* on the plan are equal in length, and *b* is the point where the rail joins the newel. Make *c g* equal in length to *c b*; draw *g f*, *c o*, and *a e*, parallel to the riser lines; through *o*, draw *h j* at right angles to *c o*. If the rail is brought to a level on the line *o j*, its height will be 9 inches from the bottom step *i* to the center of the rail at *j*. In this elevation the rail has been drawn below its real position a distance equal to the height of a short baluster, or 2 feet 2 inches. This distance, added to 9 inches, gives 2 feet 11 inches as the height of the newel, from the first step *i* to the center of the rail at *j*. If the rail is continued straight to *f* its height will be only 2 feet $5\frac{1}{2}$ inches. If the newel is designed to meet the requirements of a plan of this character, it is important to determine the exact height where the eased rail will connect, and the foregoing description will enable the student to do so.

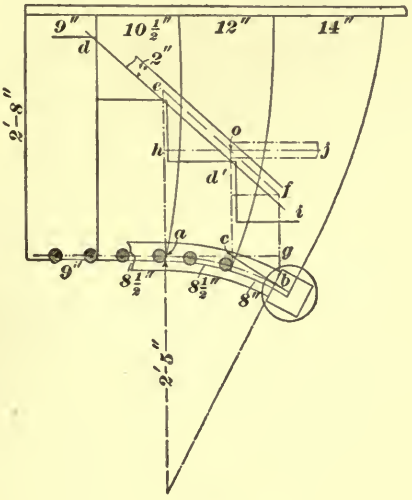


FIG. 34.

In Fig. 35 is shown a stairway starting at the newel with a curved stringer and swelled steps; the newel in this arrangement is to stand on the first step, the riser extending around to the stringer which will receive it. Thus the newel does not project beyond the line of the first step, and, where the space is limited, this method will help to overcome the difficulty. The height of the newel in this case may be determined by the method explained for Fig. 34.

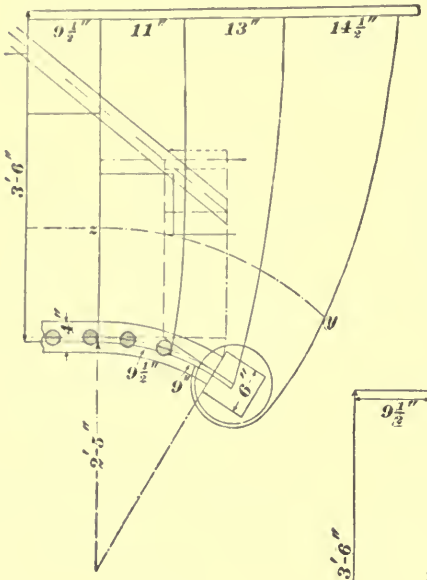


Fig. 35.

In Fig. 36 is shown a plan wherein the stringer is curved as in the previous examples, but, with the exception of the starting one, the risers are made straight.

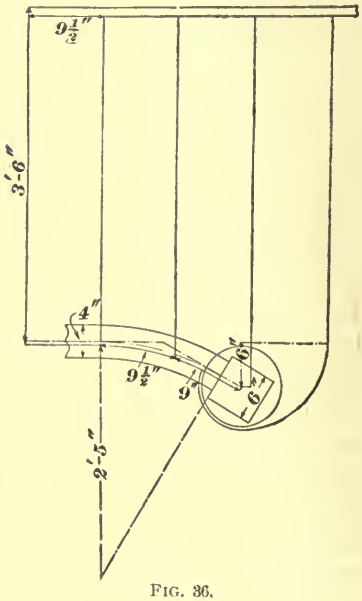


Fig. 36.

43. Curtail Step.—In Fig. 37 is shown a method of describing the curves of a *curtail step*. Begin by drawing a circle of a size greater than that required to enclose the required scroll. Let *a b c d* be such a

circle; divide it into 16 equal parts, and let the diameter of the eye of the scroll be equal to *e f*, in this case 7 inches. The diameter of the eye should always be somewhat greater than the width of the hand rail, which in the present instance is 6 inches. At right angles to *b d*, and tangent to the eye, draw *e' i*; from *i* draw *i j*, perpendicular

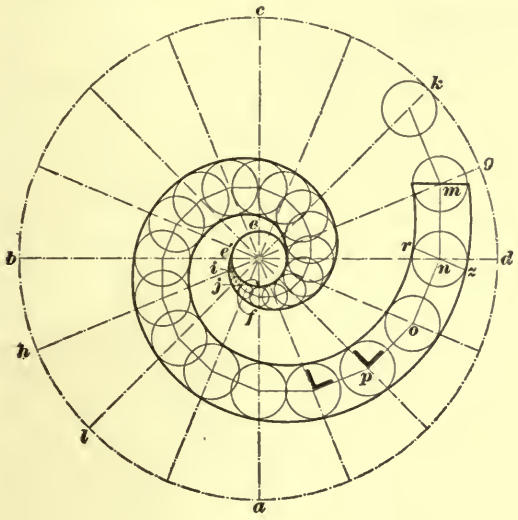


FIG. 37.

to *h g*; and so proceed, drawing lines at right angles to the successive radial lines; and continue this process to *m*, or to any point desired. From the points of intersection on the radial lines, with a radius equal to 3 inches, or one-half the width of the rail, describe arcs as shown. Tangent to these arcs, draw in an outline of the curve of the hand rails.

In Fig. 38 is shown a plan (*a*) of a curtail step with curved steps receding from same. This plan may be drawn from the dimensions shown, taking as much of the scroll delineated in Fig. 37 as is required to fulfil the conditions. At *z r*, in Fig. 38, is shown the junction of the scroll with the straight rail. Where the scroll has been developed in a diagram, as shown

in Fig. 37, the whole or any part of it may be transferred to the plan of the stairway, as was done in Fig. 38. In order to fix the height of the wreathed portion of the scroll, draw an elevation of the risers and treads as at (*b*). Draw the

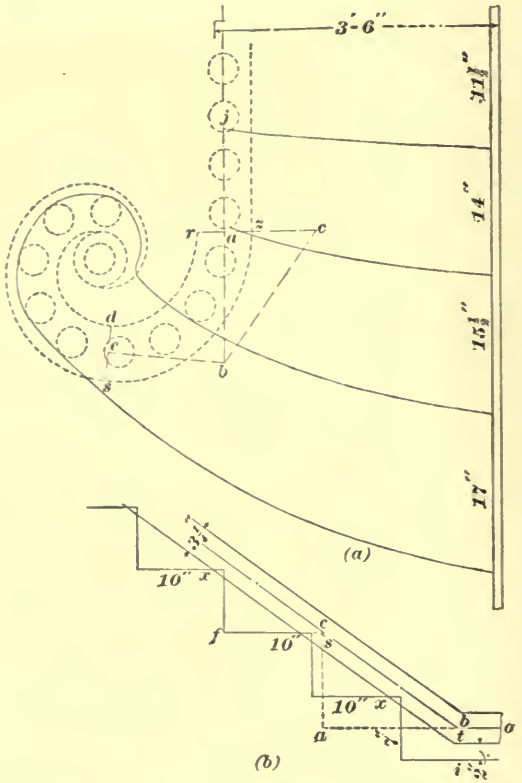


FIG. 38.

bottom line of the rail *x x* through the points on the treads where the center lines of the short balusters intersect; draw the center line *c b* of the rail; make *f s* equal to *j a* in (*a*). Parallel to the riser lines, draw *c a* through *s*; make *t i* equal to, say, 2 inches, thereby fixing the height of the eye and the level portion of the scroll. Draw *t b* equal to one-half the depth of the rail; draw *b a* parallel to the tread line.

Then, as the bottom line of the scrolled rail is 2 inches above the first step *i*, and the length of a short baluster being 2 feet 2 inches, the height from *i* to *t* will be 2 feet 4 inches, when in position. It is desirable to keep the scrolled rail as low as that shown, so that its varying and pleasing curvature will be seen to the best advantage. In the plan (*a*), *a b* is the center line of the rail prolonged, and *a c b* is taken from lines similarly lettered in (*b*). From *b*, draw *b e* tangent to the center line of the rail at *e*. The joint *s d* is made at right angles to *e b*. From *s d* to *z r* is the wreathed portion of the rail, since it both curves and rises. The remaining portion of the scroll, from *s d* to the eye, is horizontal, as shown by *b o* in the elevation (*b*), and in this part of the scroll, three or four of the balusters should be bolted to the step at their bases, and to the scrolled rail at their top. The construction of the veneered riser and scroll block is shown in Fig. 39 (*a*), and the complete scroll step is shown in (*b*).

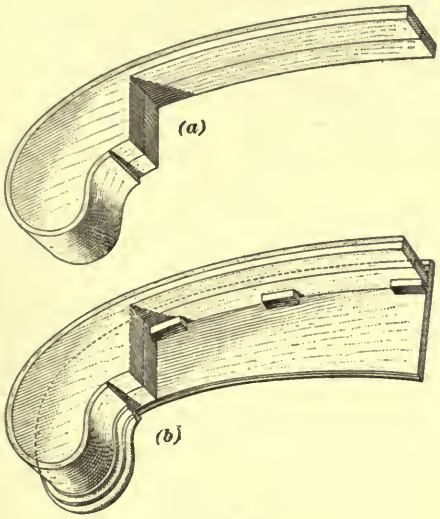


FIG. 39.

SPECIAL FORMS OF STAIRWAYS.

44. Quarter Platform.—In Fig. 40 is shown a plan of a quarter-platform stairway with a quarter cylinder for a continued hand rail. Any radius of cylinder considered desirable may be used, but if the risers *o b* and *o′ b′* be put at a distance equal to one-half the width of a tread from the

point *a*, the intersection of the center lines of the rail, the wreath piece will conform to the common pitch of the flights. If the front stringer is a close one, and the risers are placed as shown, the effect will be more agreeable than it would be if the risers were placed either nearer to, or farther from, the point *a*. This arrangement of the risers will allow of a graceful curve in the development of the front stringer and the hand rail, while if placed in any other position, the result would be an unsightly crippled rail and stringer.

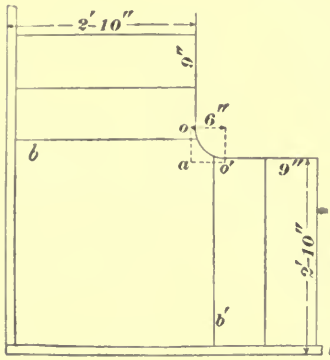


FIG. 40.

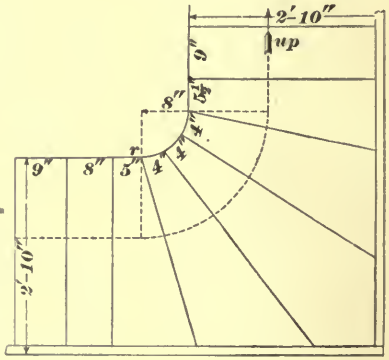


FIG. 41.

45. Quarter-Turn Winding.—The plan of a quarter-turn winding stairway, with a quarter cylinder for a continued hand rail, and with regular treads above and below, is shown in Fig. 41. It will be noticed that the treads adjoining the cylinder in both flights are reduced. The benefit derived from the reduction will appear in the curve of the rail and stringer, as it modifies the angle of intersection between the pitch of one straight rail and that over the winders, the stringer, of course, being affected in the same manner.

46. Platform and Curved Risers.—In Fig. 42 is shown a plan of a stairway which includes two platforms with a step and two curved risers in the 10-inch cylinder between the platforms, making a half turn. The wreathed rail

over this plan has a pleasing shape, and no ramp is required in the straight rail either above or below the wreath.

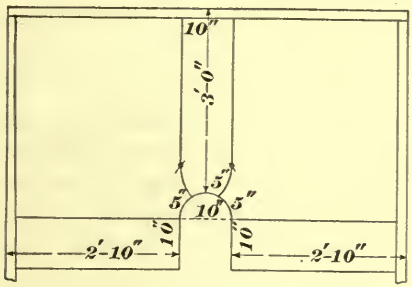


FIG. 42.

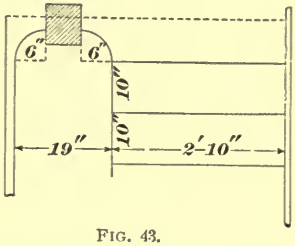


FIG. 43.

47. Newel Between Quarter Cylinders.—Fig. 43 is a plan of a stairway with a newel post set between quarter cylinders on the landing of a flight; the hand rail in this case would be bolted to the newel.

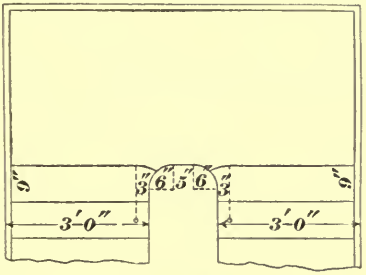


FIG. 44.

48. Half-Turn Platform.—In Fig. 44 is shown a half-turn platform stairway. The face of the top riser of the lower flight and the bottom riser of the upper flight have a slight curve adjacent to the cylinder. By this method the whole depth of the cylinder is saved in the run of the stairway—an advantage where space is limited.

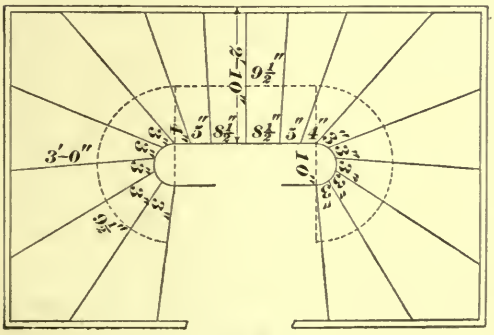


FIG. 45.

49. Winding Stairway.—Fig. 45 is a plan of a winding stairway with 17 risers, and 10-inch cylinders for a continued hand rail. This

arrangement is suitable where space is limited and where the entrance to the staircase is on the side.

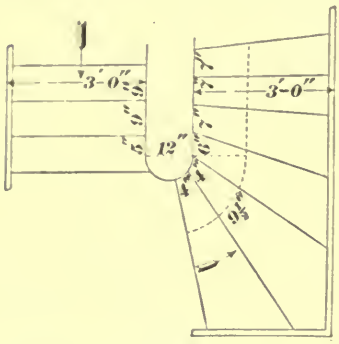


FIG. 46.

50. Arrangement for Intermediate Floor.—Fig. 46 is a plan for the starting and landing of two flights connected by a 12-inch cylinder; such an arrangement is used where the short flight ascends to an intermediate floor on the platform level.

51. Quarter Platform With Tangent Between Quarter Cylinders.—Fig. 47 is a plan of a quarter-platform stairway for a continued hand rail. The cylinder opening of 18 inches is formed by two quarter circles, each of 5 inches radius, and an 8-inch piece of straight stringer between. By this method a platform is secured, and angular winders are dispensed with; the run of the stairway is also reduced.

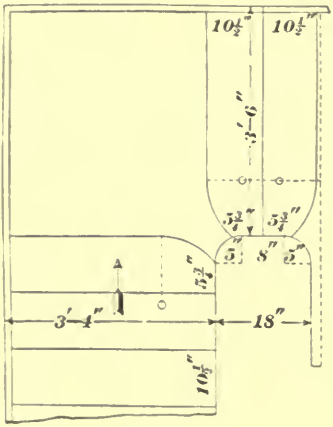


FIG. 47.

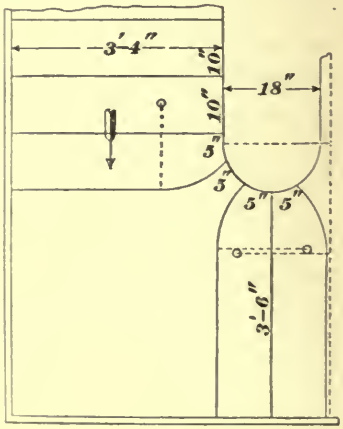


FIG. 48.

52. Quarter Platform With Semicircular Cylinder. Fig. 48 differs from the preceding plan only in the form of its

cylinder, which is semicircular in plan, and, while requiring a little more run, furnishes a more pleasing rail and cylinder.

53. Double Platforms.—Fig. 49 is a plan of a platform stairway making a half turn, one riser at the center of the cylinder dividing the space into two platforms. Where the run will permit, it is always advisable to dispense with this central riser, thus adding breadth to the platform, and avoiding the danger of stumbling at the step placed where it is not expected.

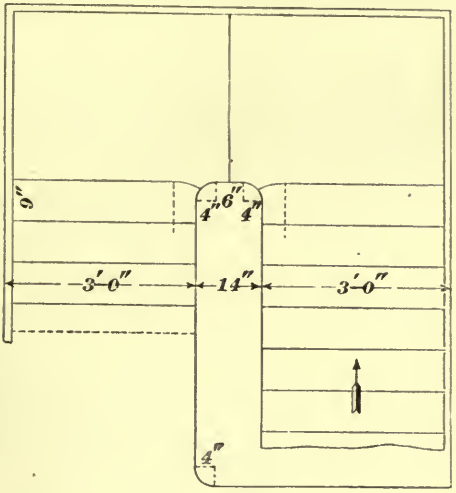


FIG. 49.

54. Quarter Platform With Step.—Fig. 50 is a plan of a quarter-platform stairway with a 15-inch cylinder having a regular step at its center.

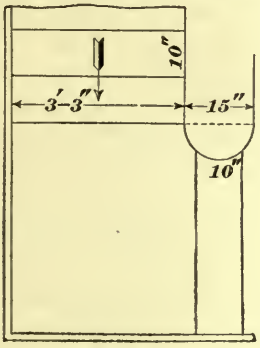


FIG. 50.

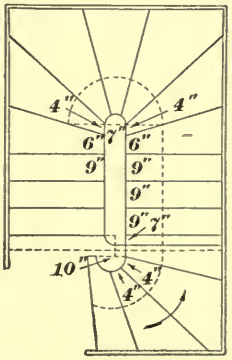


FIG. 51.

55. Three-Quarter Turn.—Fig. 51 is a plan of a winding stairway making a three-quarter turn, the entrance being at one end of the staircase.

56. Starting or Landing Winders.—Fig. 52 is a plan of a stairway which has winders either at the starting or at the landing. The curving of the risers is resorted to for the purpose of making them occupy less room from *l* to *m*. Curving the risers in this manner also improves the appearance of the stairway, by reducing its angularity.

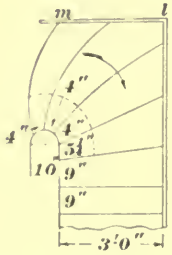


FIG. 52.

57. Quarter Platform With Newels.—Fig. 53 is a plan of a quarter-platform stairway with small newels framed to the stringers in the angles; the hand rail may join the newels either straight, or with easements and with ramp and knee, or with a goose neck. The curved risers are introduced to save the space in the run of the flights.

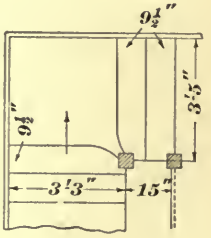


FIG. 53.

58. Platform Stairway With Two Return Flights. Fig. 54 is a plan of a platform stairway with two return,

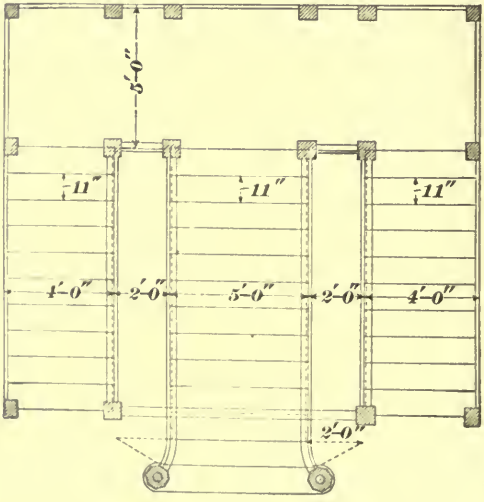


FIG. 54

or *wing*, flights, suitable for a public building. The flights and platform may be wainscoted, and, by the introduction of half newels set against the wall opposite the regular newels, a good structural effect is obtained. The regular and wall newels may be carried up as columns and pilasters, further improving the treatment. The flat, ornamental arches may also be introduced between the newels and half newels, to break up and panel the soffit spaces. For a public stairway of this character, executed in either wood or iron, a better effect is produced by omitting the plaster and showing the framework of the structure.

59. Circular Stairway.—A plan of a circular stairway is shown in Fig. 55; all the risers except the three curved ones at the start radiate from the center *b*, and are equally spaced at the front and wall stringers. The first two steps are curved out, to increase the width of the stairway at the start, thus giving it a more pleasing appearance. A curtail step and hand rail at the starting of such a stairway is very appropriate and attractive. The dotted lines indicate the position of the carriage timbers. A similar method may be followed for elliptic stairways.

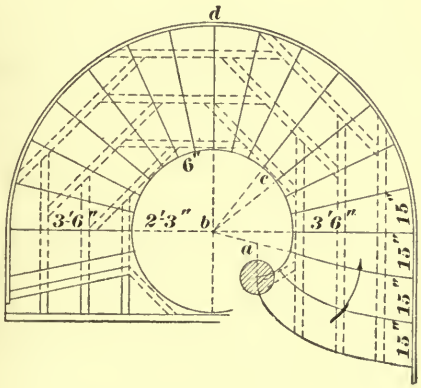


FIG. 55.

Instead of a cylindrical front stringer, as in this plan, a circular newel post of sufficient length is sometimes used as a central support, the treads and risers being framed into the central newel and into the wall stringer. The newel post may be cased with $\frac{7}{8}$-inch boards of the same width as the treads at the point of connection, affording support and enclosure like mortises to the steps; the spaces for the risers

may also be cut out from the edge of the boards, thereby rigidly securing them. This casing, or staving, would not be set in place until the steps were all nailed in position.

60. Elliptic Stairway.—In Fig. 56 is shown a plan of an elliptic stairway. The usual method of providing a uniform width for the treads along the wall stringer, and also along the front stringer, causes some of the risers to stand

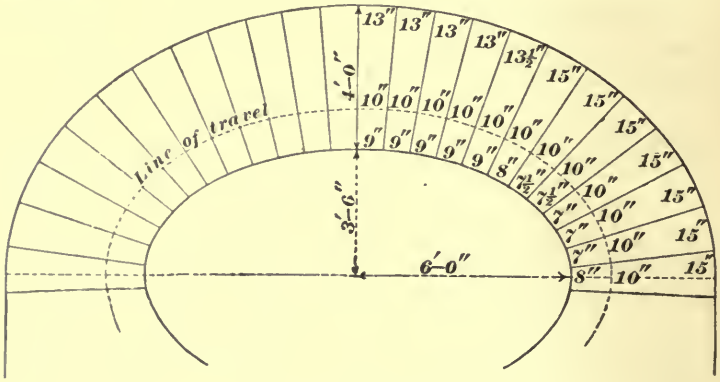


FIG. 56.

at such an angle with the line of travel as to diminish the width of treads at that point. It has the advantage, however, of giving the hand rail a uniform pitch from end to end. In the plan shown, the treads are divided equally on the line of travel, and the risers are drawn as nearly as possible normal to the front stringer.

WAINSCOTING.

61. The paneled wall lining for halls and stairways is made of various heights, the arrangement and treatment of the panels being varied to meet the ideas of the designer. In Fig. 57 is shown a portion of wainscoting as it passes from the hall up the flight. A vertical section of the framework panels and moldings as usually made, is shown at *D*, in which *a* is the baseboard; *b*, the bottom rail; *c*, the panels;

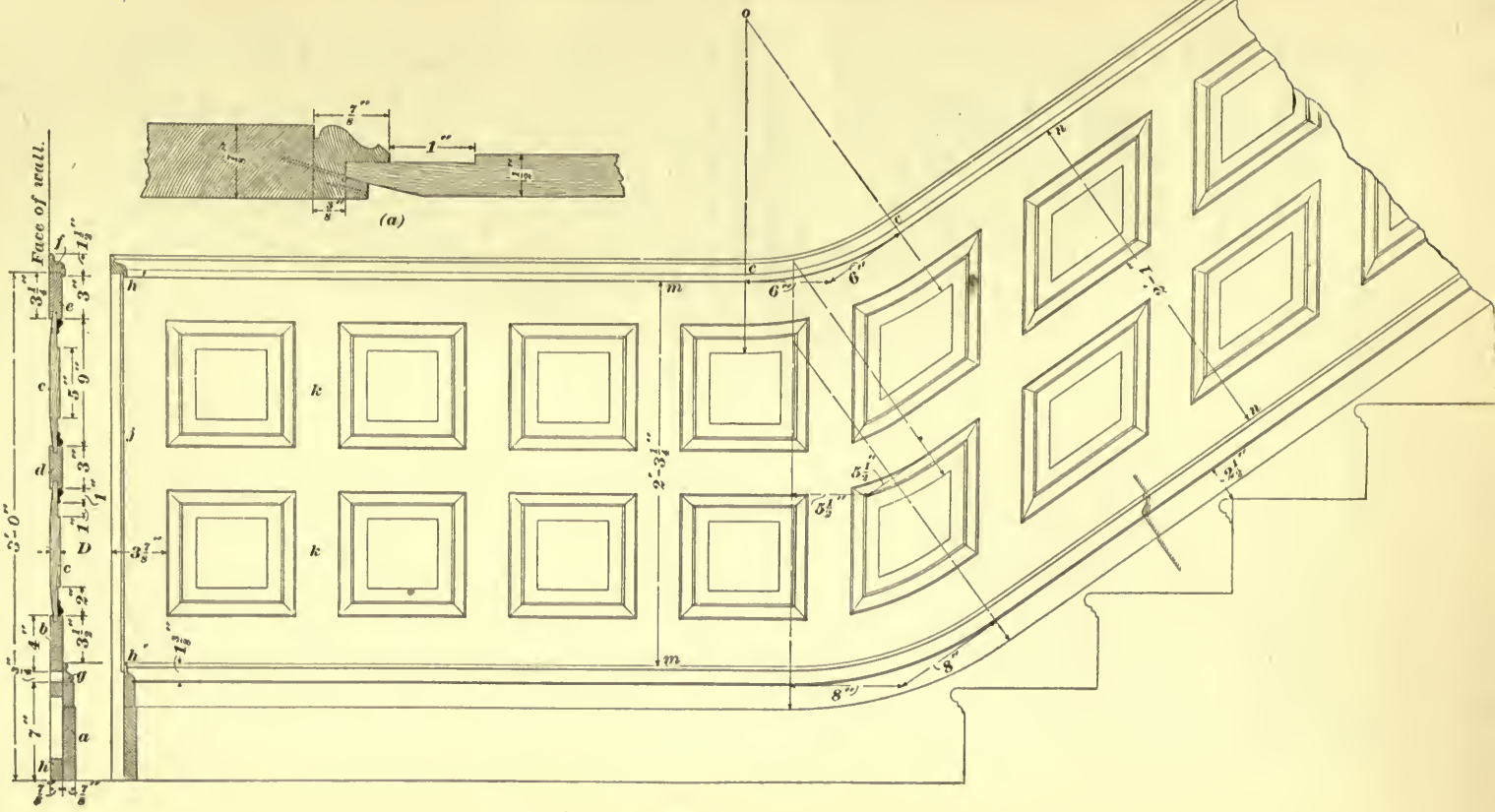


FIG. 57.

d, the middle rail; *e*, the top rail; *f*, the cap molding; *g*, the base molding; and *h*, the furring strip. In the elevation, *h' h'* is a stile with a groove *j* to receive the return wainscoting; at *k*, *k* are muntins. The stile *h' h'* extends the whole height, and the three rails are framed into it. The panels are square on the level portion, but up the flight they become lower, as the width of the wainscot *n n* is less than the width *m m*. The curves at the junction of the pitch and level lines are described from three different centers, as shown. The curves cannot be described from a common center, as the two portions are not of the same width. By producing the tangents of the level and inclined portions of the top, bottom, and central rails, and deciding on the length of the curves, radial lines may be drawn from the points, as at *c*, *c*, thus locating the center, from which simple curves may be drawn. At (*a*) is shown a method of fastening the panels whereby no nails show on the face of the molding.

The panels are polished separately, and put in place after the frame and moldings are finished. The framework should be well seasoned, and the walls should be perfectly dry before the wainscoting is set in position.

ORNAMENTAL IRONWORK.

INTRODUCTION.

1. Iron is used in building construction to serve two purposes, one structural and the other ornamental; but becomes an element of architectural consideration only when both purposes are combined. Unfortunately, the facility with which iron may be cast or wrought into any desired form, renders the execution of the whole facade of a building as simple as though it were constructed of wood, and imbues the ironwork designer with a tendency to ignore the characteristics of the material with which he is working, and to execute columns, capitals, and friezes in cast iron, with fidelity to original examples which were carved in stone, and whose designs are ill suited to iron.

However, the incombustible character of this material, and the fact that its use materially shortens the time and decreases the expense of erecting a building, render it certain that iron as a building material is as important at the dawn of the twentieth century, as was stone before the Christian era; and instead of condemning it as an "unarchitectural material," as some are inclined to do, it is our duty to study its character and possibilities in design, and to develop a system or scheme of design which will be consistent with the conditions imposed by the material and its structural use.

To do this it will be necessary for the student to understand the method of manufacture, and difficulties attendant upon the execution of any design in ironwork, so that in preparing a design he may keep it free from impossible demands. For instance, if the design is for a piece of cast-iron work, the designer must provide a means of molding the form properly, and of getting the fluid metal into the mold without injuring any of the finer details. If the design is for a piece of wrought-iron work, such as a grille or a railing, provision must be made for enough space to permit riveting, hand welding, etc.

Thus it will be seen that a careful consideration of the methods used in general shop practice, will be the best way for the ironwork designer to advance in the comprehension of his work. This section will, therefore, treat of the details of shop and field work in connection with the manufacture of iron for architectural purposes; and, therefore, the illustrations of working drawings used herein to elucidate the text are reproductions of drawings which have actually been used in the preparation of ironwork for some of the most important buildings.

The first part of the paper will consider cast-iron work, while the manufacture of wrought iron and the combination of cast and wrought iron will follow consecutively.

CAST-IRON WORK.

METHOD OF MANUFACTURE.

DEFINITIONS OF TERMS.

2. **Cast iron** is the term given to that quality of iron which exists when the melted metal is poured into a suitable receptacle, or *mold*, and allowed to cool and solidify. Cast iron is hard, brittle, and somewhat crystalline in its composition—that is, it shows on its fractured surfaces an appearance resembling an aggregation of small crystals,

instead of a fibrous fracture like wrought iron. It is used, architecturally, for columns and newel posts, and, under certain conditions, for lintels or beams; but, owing to its lack of elasticity, it is not well adapted to conditions of transverse strain. It is also formed into slabs for the purpose of stair treads, pavements, etc., and some forms of ornament are cast and attached to purely structural details.

3. Molds are the receptacles into which the molten metal is poured to give it some definite form consistent with the purpose the cast iron is to serve in the building. The molds are made by impressing in sand a cavity or a number of cavities which correspond, in shape and relation of parts, with the contour of the object to be cast. The process of so impressing the sand is called *molding*, and is effected by means of a wood or plaster model of the object, called a *pattern*, which is so embedded in the sand that it will leave its impress when withdrawn.

4. Patterns are generally made of wood, though sometimes of plaster, and occasionally partly of each. Where there are to be a great many castings of one kind, the pattern is sometimes made of bronze or iron, in order to stand the wear, but even in such cases the bronze or iron pattern would be cast in a mold originally impressed with a wood or plaster model. Whether a pattern shall be of wood or plaster depends entirely on the character of the work. Plain straight work, such as molded panels, stair strings, columns, etc., is generally made of wood; but ornamented moldings, decorated panels, complicated capitals, etc. are first modeled in clay or wax, from which a cast is taken in plaster.

All patterns must have an allowance made for **shrinkage** —that is, the contraction and consequent decrease in size which every casting undergoes in the process of cooling. In ordinary work this amounts to about $\frac{1}{8}$ inch per foot in every direction, so that the patternmaker in working from full-size drawings must use a *shrinkage rule* to lay out his work. The shrinkage rule is usually a little over 2 feet in length and

the divisions on it corresponding to 1 foot are in reality 1 foot and $\frac{1}{8}$ inch, and the subdivisions are proportionately excessive. Consequently, the pattern for a cast-iron bar 1 foot long, 3 inches wide, and $1\frac{1}{2}$ inches thick, would measure 1 ft. $0\frac{1}{8}$ in. long, $3\frac{3}{32}$ inches wide, and $1\frac{3}{64}$ inches thick.

In order that they may be freely withdrawn from the mold, patterns are worked with a **draft,** or taper. For example, if the object to be cast is a solid bar 1 ft. 3 in. long and 3 inches square in section, as at (*a*), Fig. 1, it would be found in lifting the pattern from the mold that the sand had a tendency to cling to the sides and thus destroy the mold. But if the sides of the pattern are slightly beveled, as at (*b*), this tendency is overcome, and the sides of the mold are left clean and sharp; therefore, in all cases where it is possible, all surfaces that occupy a vertical position in the mold should have an allowance for *draft*. The exact amount of this allowance cannot be given, as in some cases it is desirable that there should be as little as possible, while in others it may be quite considerable without in any way impairing either the purpose or the appearance of the part.

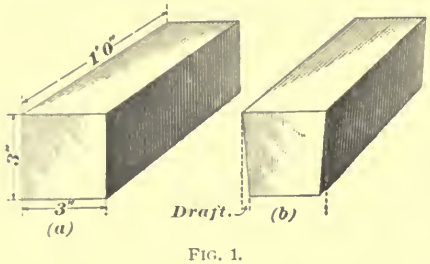


FIG. 1.

5. Casting is the operation of pouring the molten iron through the inlets—or *gates*, as they are called—into the sand mold from which the pattern has been withdrawn. All the above described details culminate in the casting. The making of the pattern, with its allowances for shrinkage and draft, the preparation of the mold with its inlets and gates, and all the details attendant thereon, are for the sole purpose of securing a perfect casting, and all conditions and contingencies must be considered before the metal is poured.

6. Suppose, for example, a newel post, such as is shown in Fig. 2 (*d*), is to be cast with ornamental panels on each of the

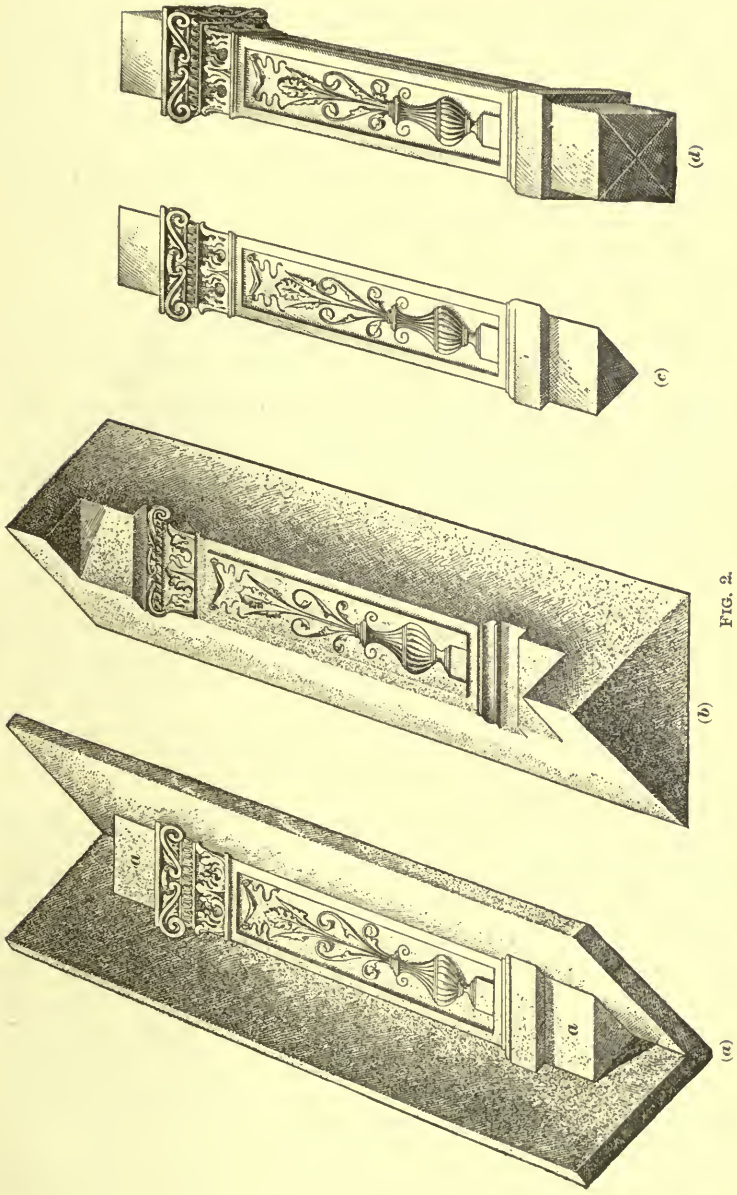


FIG. 2.

four sides. The first step is to prepare the model; and, as all sides are alike, one complete side is therefore modeled in clay, from which plaster casts are taken and combined to form the complete pattern shown in Fig. 2 (*d*). The simplest method of making this pattern is in halves, with the joint at the corners. One-half of the pattern is then laid on a board, as shown at *a*, Fig. 3; and one-half of the mold-

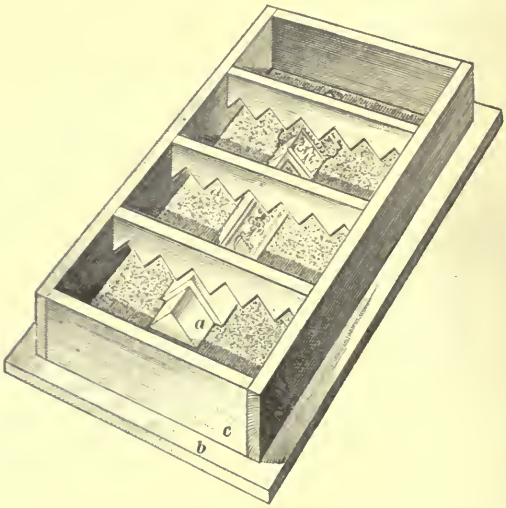


FIG. 3.

ing box *c* is laid over the board *b*, as shown. The sand is then rammed tightly all around and over the pattern, and the mold turned upside down. The board *b* is now removed, and the other half of the pattern is laid in place. The upper part of the molding box is then placed over the lower part, and filled with sand around the upper half of the pattern, as before. The top part of the mold is now lifted off and the pattern withdrawn, leaving one-half of the mold, as shown at (*b*), Fig. 4; but, as the casting is to be hollow, a *core* will be necessary to form the cavity. This core consists of a block or bar of sand, the size and shape of the hollow portion, or inside of the casting, as shown at *d*, Fig. 4. The core is supported at each end in recesses *g* formed for the

purpose by projections on the pattern called *core prints.* When the core *d* is in place, the recess *f* shows the thickness the metal will be when the newel is cast.

The core is made of sand mixed with oil and flour, or some similar composition, and is molded in a box especially made for it; it is then baked hard in an oven before it is ready for use. The core being adjusted, the molding box is closed.

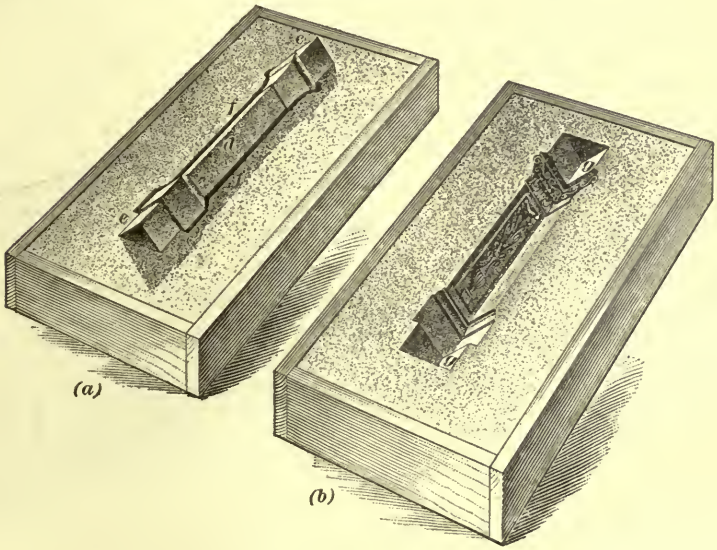


FIG. 4.

and the two halves are clamped firmly together. When filling the top part of the molding box with sand, a passage is formed reaching down to the part to be occupied by the cast metal; small holes are also left for the gases to escape which might otherwise destroy the mold by explosion when the molten metal is poured through.

This method of molding is the simplest, and is perfectly suitable for any plain casting, but in a more elaborate piece of work, the ornament of which is *undercut*, as it is termed, a different method must be resorted to, or the undercut portions, when withdrawn from the mold, will tear out a part of the sand with them. There are several devices for overcoming

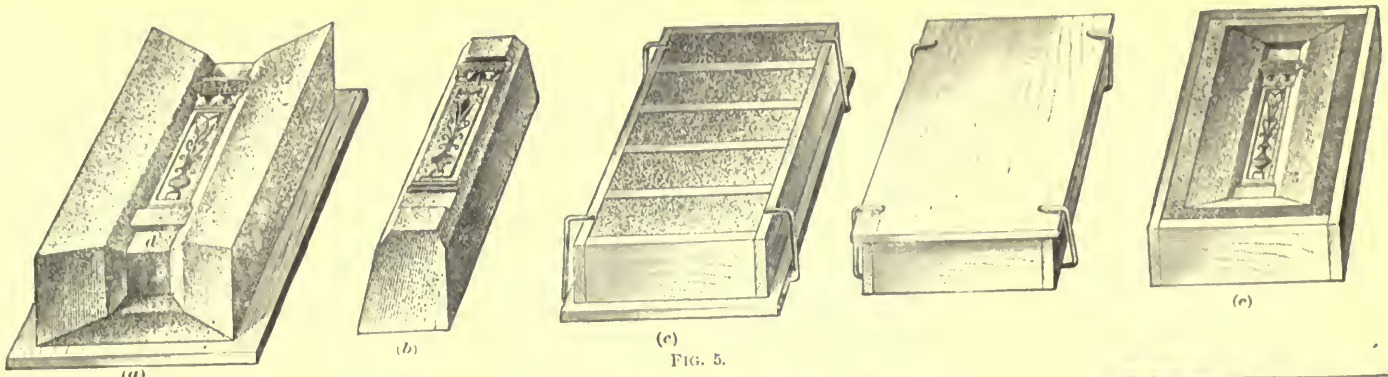
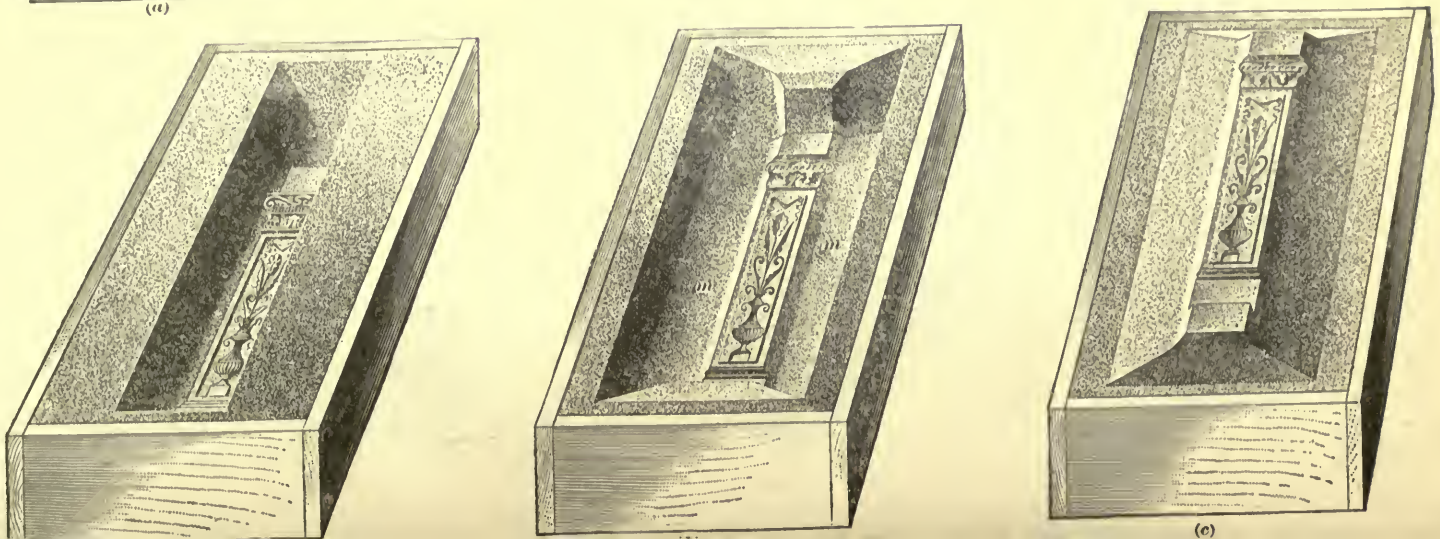


FIG. 5.



this difficulty, such as making these parts loose or detachable on the pattern, so that after withdrawing the main part of the pattern, these pieces are left in the mold and can be picked out separately. A better method is to prepare a pattern of plaster somewhat as follows:

7. In the angle formed between two wood or plaster slabs, set as shown in Fig. 2 (*a*), the pattern is molded in clay, leaving a projection at each end, as shown at *a*, to form the core print.

When the clay model is complete, it is coated with shellac varnish, and the sides of the slabs are oiled. A plaster cast is then taken of the clay model, as shown in Fig. 2 (*b*). This mold, when it is dry, is itself oiled, and from it are made four additional plaster casts, as shown in Fig. 2 (*c*). The purpose for modeling the original pattern in the angle between two slabs is now apparent, for in molding the four final casts the plaster is simply poured on top of the mold, Fig. 2 (*b*), and roughly heaped up to form a ridge; then, by drawing a straightedge against each side of the mold in turn, the resulting casts are properly mitered, and may be secured together with shellac, forming a complete model, as shown in Fig. 2 (*d*). The undercut portions are so arranged that no seams, loose parts, or cores are necessary, and the danger of displacement is overcome by treating the pattern as follows: The pattern is laid on a board and leveled up, as shown at *d*, Fig. 5 (*a*). The ornament at several points may rest on the board, but the body will be clear. It is then bedded up with clay, sloping the clay from the line of the lower edge of the pattern gradually down to the level of the board; then the pattern is oiled to keep the wet plaster from sticking, and a plaster cast is made of both sides, sloping the plaster upwards to the top edge, and beveling the sides and ends as shown, the object of which will be seen hereafter.

In Fig. 5 (*a*) the pattern is shown resting on a board, with the two plaster casts of the sides completed and lying against it. These casts or molds, when detached, appear as shown in Fig. 5 (*b*).

In the same manner, a plaster mold is made from each of these blocks. As these molds will be used in the foundry repeatedly, they should have a rough wooden frame to protect them from fracture, as shown in Fig. 6 (*a*).

Two blocks, such as shown in Fig. 5 (*b*), are attached firmly with shellac to each side of the original pattern, thus bringing it back to the form shown in Fig. 5 (*a*). The pattern thus treated is ready to be put in the sand.

The pattern *d*, Fig. 5 (*a*), is now laid on the molding board, and one-half of the molding box placed over it, and rammed full of sand, as shown in Fig. 5 (*c*). It is then turned over in the position shown in Fig. 5 (*d*), and the temporary clamps and the molding board are removed. The face of the pattern when brushed off will then appear, as shown in Fig. 5 (*e*). The upper part of the box is then put in place and rammed up with sand, and then the box is opened and the pattern removed. The mold is left one-half in the lower box, as shown in Fig. 6 (*b*), and one-half in the upper box, as shown in Fig. 6 (*c*). The plaster mold, Fig. 6 (*a*), is filled with sand, and also the corresponding mold for the other side, thus making two blocks which correspond in shape and size with the recesses *m*, *m* left in the mold, Fig. 6 (*b*), into which they are carefully slipped. The core is put in place and the molding box closed. The mold is now ready for the metal, it being understood that gates and outlets have been provided.

8. In the process of casting, it is not good practice to have heavy members cast adjacent to much lighter ones, because, as the lighter parts cool so quickly, compared with the heavy portions, the result would be disastrous, on account of the unequal shrinkage of the metal. The thin members do all their shrinking in a very short time, and in so doing are likely to crack away from the thicker parts, which would have retained the heat longer and consequently have shrunk to a lesser degree. This is not to be taken to mean that every casting must be one dead level of thickness all through, but where there are variations of this sort adjoining, thick

and thin sections should be graded gradually together, avoiding as much as possible any very abrupt transition from one to the other.

A casting designed without regard to this matter may be molded successfully, and, in some cases, the unequal shrinkage of the parts avoided by opening the box as soon as the iron has had time to solidify, and exposing the thick portions to the atmosphere, while the thinner parts remain covered with the sand, that they may retain the heat for a longer period, thereby somewhat equalizing matters. The fact remains even then that there would be a certain amount of latent strain left, likely to be sufficient to cause a subsequent fracture when the casting is subjected to a sudden jar or impact.

Having thus far described the use of iron as a medium for decoration, and the processes generally used for cast-iron patternmaking, molding, and casting, the different structures and parts generally made of iron will now be considered.

STRUCTURAL DETAILS.

9. Screws and Bolts.—In Fig. 7 at (*a*) is shown what is termed a *square-head* bolt. These are used for all common connections, such as the joining of two flanges or other

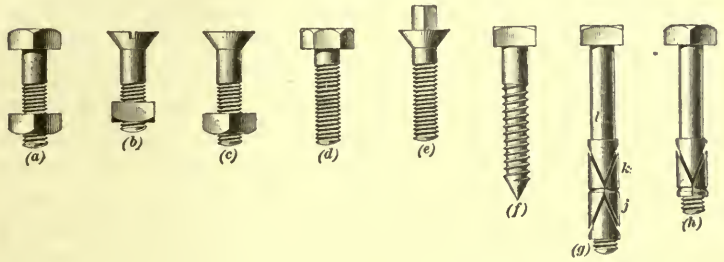


FIG. 7.

surfaces which are not exposed to view. At (*b*) is shown a *screw-head* bolt, which is used for work where a countersunk head is necessary in order to obtain a smooth surface, the

slot in the head being filled with putty after the work is in place.

At (*c*) is shown a *countersunk-head* bolt used for the same purpose as a screw head, and also for securing wooden stair treads to wrought-iron strings, so as to permit the head to finish flush with the tread. A *button-head* bolt with a square shoulder is also used for the same purpose, the shoulder aiding in the tightening of the nut. The countersunk bolt is also used in joining flat surfaces where a smooth finish is required. At (*d*) is shown a *tap bolt*. This is used for all connections where it would be impossible to get a nut on the end. The hole into which this bolt is to be screwed has a thread cut in it, or is *tapped*, as the technical phrase would express it.

At (*e*) is shown a countersunk tap bolt which is used where very heavy work is to be joined, and requires a smooth-finished surface. After the bolt has been tightened up by the aid of a wrench, the square head is cut off.

Lagscrews, shown at (*f*), are used to secure iron to stonework or woodwork; a plug of soft metal or wood is driven in a hole drilled in the stonework and into this the screw is inserted.

At (*g*) is shown a double-expansion bolt, which is used for fastening work to smooth surfaces, as brick or stone walls. This bolt consists of four pieces and a nut. The bolt is inserted in a hole drilled in the wall for it, and over it is slipped the expansion piece *j*; the expansion piece *k* is then put in place, and finally the expansion socket *l*. The nut is then turned down against the article to be secured, and the expansion socket *l* is forced down, while the bolt draws up, and the prongs on *j* and *k* expand, taking hold in the stonework and binding in the strongest manner possible. The single-expansion bolt (*h*) acts in the same way, and is used for the same purpose. The chief advantage of these bolts is that they may be taken out without damage to the surrounding stonework.

Expansion bolts are also made with screw heads, for use where the surface will be exposed to view.

10. Mullions.—A window such as shown in Fig. 8 is sometimes so wide that it requires a mullion, and the design of this mullion must be consistent with the rest of the building, no matter what its construction may be. There are three ways of constructing the mullion: (1) with an upright **I** beam, and cast-iron facing, as shown in plan at (*a*);

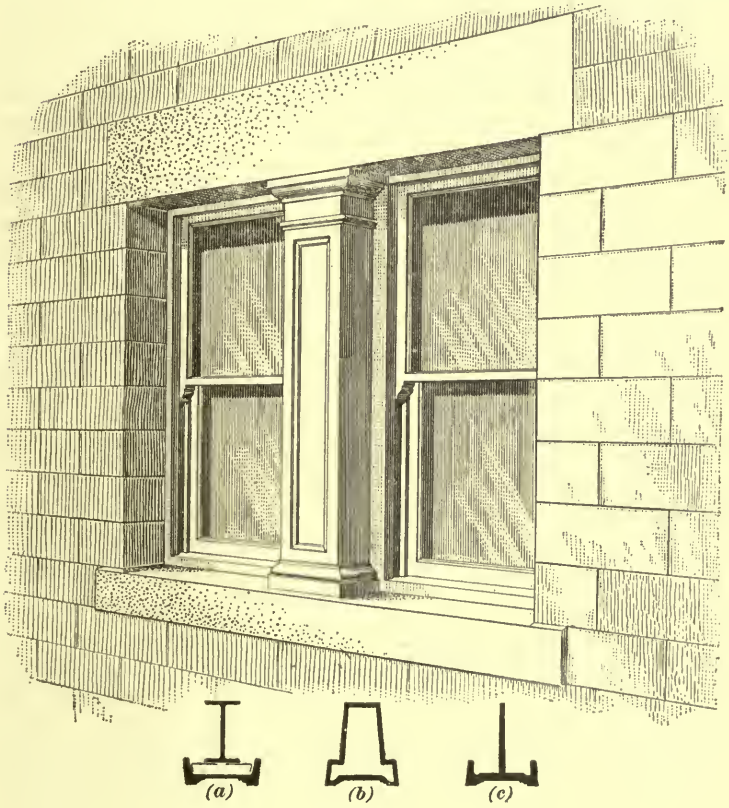


FIG. 8.

(2) with a cast-iron box on which the ornament is cast, as at (*b*); and (3) a modification of the two preceding, which consists of a **T**-shaped casting with the ornament on the face, as at (*c*). The advantage of the first method is that the ornament may be applied without regard to the structural

support, while in the other two, sufficient allowance must be made in the thickness of the metal to proportion the support to the load.

In the first example (*a*), the cast-iron facing is screwed or bolted to the I beam. The decoration may be a simple panel as shown, or a highly ornamented arabesque, according to the requirements of the design, for so long as the sides are plain, the casting of the mullion presents no particular difficulty, being but a plain panel, the pattern for which would be of wood about $\frac{1}{2}$ inch thick with the sides slightly beveled or drafted to allow it to be drawn freely from the mold.

The length of the mullion is 8 feet; therefore, the pattern should be 8 ft. 1 in. in length, to allow for shrinkage.

If the design of the mullion be ornamental, the pattern may be entirely of plaster, or the body of wood and the ornament modeled in clay. If there are to be a number of these mullions in the facade, only one model is made; and, by covering this with plaster of Paris, a mold is obtained from which any number of wax duplicates can be cast of the original, which are then mounted on the body of the pattern for the mullion.

In the second case (*b*), the pattern should be made in a similar manner to (*a*), but, in addition, a core box is necessary, in which the sand core is made to be placed in the mold so that the desired thickness of metal is obtained. The sides of this mullion are checked or rebated to receive the window frames, while in (*a*) and (*c*) the frame passes back of the reveal or side.

The third case (*c*) should only be used where the superimposed load is small; its chief advantage lies in the fact that it does away with the use of the I beam without requiring a core for the casting, saving thereby both in the cost of manufacture and in the setting.

11. Window Frames.—The section of the window soffit shown at Fig. 9 shows a cast-iron frame, the outer edge of which takes the place of the weather stop, and is

ornamented with an egg-and-dart molding. The section of the iron jamb and head shown at *a* are for either a stationary window set directly in the iron frame or a French sash window, the hinges of which are secured to the iron frame with countersunk tap screws; or, when a wooden hanging stile is introduced, as shown at *b*, a pivoted sash may be used. The decoration of the weather stop and the inside of the frame should conform to the general design of the building.

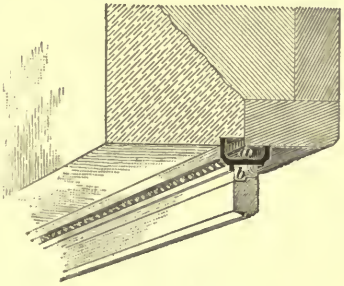


FIG. 9.

The pattern for the body of the frame would be modeled in wood, and the decorated parts done in clay, cast in plaster, and applied to the body of the pattern. The outer and inner faces of the frame should have considerable draft, as shown, so that the casting may be easily withdrawn from the mold. If the requirements of the case demand a transom bar in the frame, its construction should be somewhat as shown at *e*, Fig. 10. A lug is cast on each side of the frame, and the transom bar is secured to these lugs with countersunk screws. The position of the sash is shown at *f*, and the transom may be hung directly from the iron frame at the top, or pivoted, as described in Fig. 9.

12. It frequently happens that the window-frame casting includes the outside casing and molded reveal, as in Fig. 10, which shows a richly ornate soffit. In this case the reveal of the soffit *a*, or the jamb at the side of the opening, is first set, then the frame *b* is put in place, and last the casing, or architrave, *c*, the head of which is checked into the stone. The only difference in the modeling and casting of these pieces is that the architrave *c* has the rosette ornament, while the reveal *b* has a repeating ornament modeled and cast separately. By this procedure, only one model is required for the rosette, and one for the repeating ornament;

and castings from these are taken until the required quantity is obtained. Thus, in case of a failure in casting the ornament, the entire casting of the soffit or architrave is not

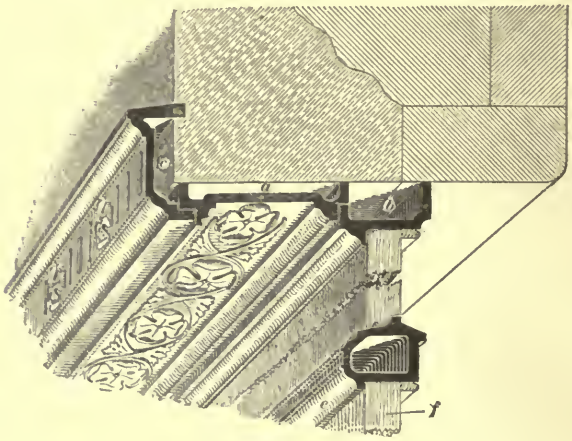


FIG. 10.

made worthless, as it would be if the ornament was cast with the main detail in one piece and a portion of the ornament proved defective.

13. Door frames may be most elaborate, or plain and simple. As a rule, when cast iron is used for a door frame, it is more properly a jamb and architrave, though in some cases the door frame proper is of iron, the same as a window frame, and the hinge butts are secured directly to it, unless a regular wooden door frame has been provided. The design shown in the illustration, Fig. 11, is the soffit of a simple molded jamb and architrave, the wooden door frame fitted against it. Both

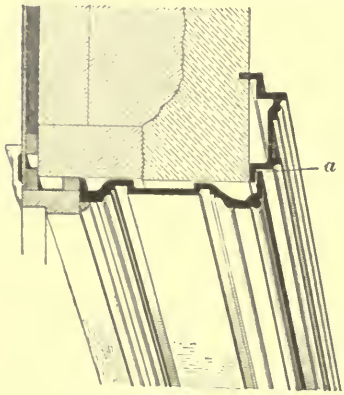


FIG. 11.

the jamb and the architrave are secured to the stonework with expansion bolts, and the joints bolted together with countersunk screw bolts. In designing a door frame, the two chief points to bear in mind are the "draft" and the proper location of the joint between the two pieces. All joints of this character should be specially designed, and so placed that they may form the meeting line between two moldings, as shown at *a*, so that they may be practically invisible. In very large work, and in buildings that are entirely of iron construction, it is better to set up a series of jamb pieces 2 feet apart, of $2'' \times 2''$ angle iron to bolt the door jambs to, the inside ends of which have knees, to which the door frame proper is bolted. The architrave should also have an angle-iron frame set up against the stonework and secured with expansion bolts, and the architrave should be secured to this with countersunk screw bolts.

CAST-IRON STAIRS.

STRAIGHT-RUN STAIRS.

14. Stairways in public buildings should be of iron, and by reason of the prominence of their location it is usually necessary that their design should be in accordance with their surroundings. A number of stairways are herein shown, not to give a variety of examples, but to illustrate the different conditions that are likely to arise in building. Any of these designs may be stripped of its ornament and be used in the plainest of structures, or the ornament may be increased and the design made suitable for a most elaborate interior. The stairs shown in Fig. 12 are suitable for such use as a basement stairway, or in a place where two floors are leased or used by one occupant, and a communication between them is necessary independent of the public halls and stairs.

15. In laying out the drawings for this flight of stairs, locate the center line of the newel *d* one inch from the face of the beam *e*, and the face of the last riser at the center of

the newel, and from this riser measure off 15 times 10 inches, or 150 inches (there being 15 treads), which will be 12 ft. 6 in., and there locate the position of the face of the first

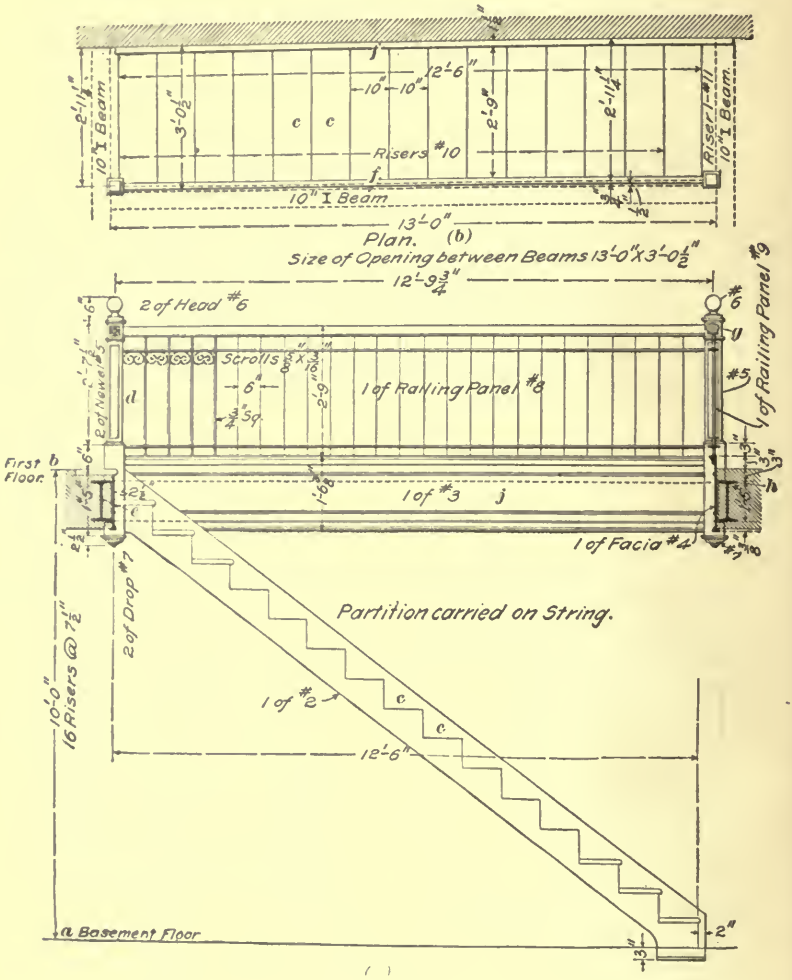


FIG. 12.

riser. The framed opening of the well through which the stair is raised is more than the length of the stair, so that

the headroom does not necessarily have to be considered. The width of the opening is 3 feet, and the strings *f* must not be more than that distance apart over all. The rise, the tread, and the position of the newel, the first and the last riser, and the width of the opening being fixed, a plan, as at (*b*), should be laid out, then the section (*a*), which shows the inside face of the string which finishes against the newel. The outer string should be similarly laid out. The next point to consider is the finish of the well; this, as shown in the section (*a*), has a molded facia *j*, a light hand rail of wood, and a balustrade of wrought iron composed of $\frac{3}{4}$-inch square balusters with a top and a bottom rail, and two additional rails forming a frieze and dado through which the balusters pass, making a very stiff rail. The moldings on the facia *j* are so placed that they come inside the face of the wall string, as shown at *f*, against which they abut. The newel *g* and the end rail are set $1\frac{1}{4}$ inches from the flange of the beam *h*. These points fixed, the general layout is complete and the next procedure is to make the several parts in detail.

16. The first piece to detail is the string *f*, the sectional shape of which is shown at *i*, Fig. 13 (*c*). The lug *k* is cast on the string, and supports the ends of the treads. The heads of the strings are cast with the base or lower part of the newel on them, and are shown in plan at *d*, Fig. 13 (*b*), and in section and elevation at (*a*). The plan (*b*) shows a lug *l* cast on the back of the newel which holds the string in place, and is secured to the flange of the beam with a hexagonal-headed bolt; the lug *m* is cast on the inside of the newel to receive the last riser. The stair strings are stiffened and anchored to the walls by the plate and brace device shown at *u* in Fig. 13 (*c*), and are set sufficiently far from the wall to receive the plaster or other finish at top and bottom. At *o* and *p*, Fig. 13 (*a*), a small allowance is made for any variation that might arise, thus enabling the erectors to raise or lower the stairs a fraction of an inch in case of necessity.

The angle newel is secured to the beam in the same manner as the newel *d*, and is cast with two lugs, so as to receive both the end and the side facias. These facias are cast with ribs *r* [see Fig. 13 (*c*)], along the back 2 feet apart, in order

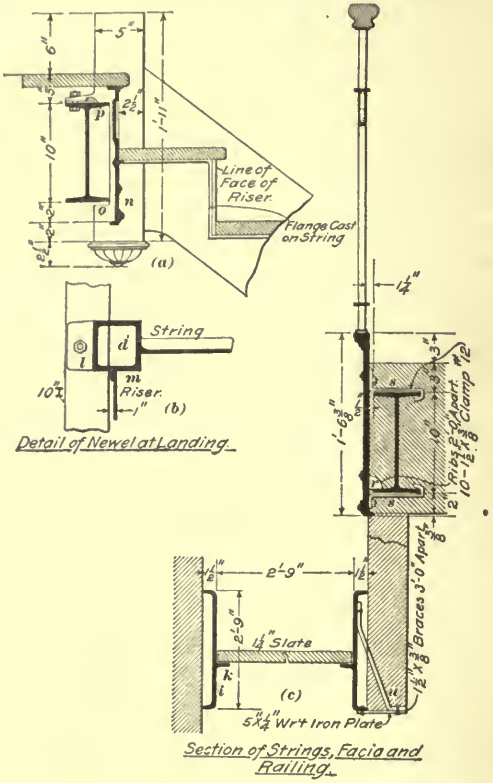


FIG. 13.

to stiffen and support them. The facias are held in place by wrought-iron anchors *s* to which they are bolted with hexagonal-headed bolts, which enable the erector to use a wrench in this close place.

17. The **newels** are cast with the upper part of each separate. A wrought-iron rod runs through the base and the shaft of the newel, the lower end passing through a

plate in the base, and the upper end through a plate in the head of the shaft; the newel is thus held firmly together when the nut is screwed on. The caps of the newels are cast with a shoulder and secured to the newel with countersunk screws. The lower rail of the balustrade is secured to the facia with countersunk screws, and the upper rail in the same manner to the newel.

In Fig. 14 is shown one of the risers, which, except the top one, are all alike. The flange *v* in the section is cast on the lower edge, and receives the marble or slate tread, and the nosing *w* is extended at the back to give a bearing for the tread. At *x* is a check, in which the lug of the string fits. The upper riser of the flight differs from all the others, as it must be wide enough to form a facia and finish under the stairs, as shown at *n* in Fig. 13 (*a*), and at the same time provide a stop for the plaster of the ceiling. The method of casting is not described, as it is perfectly plain work.

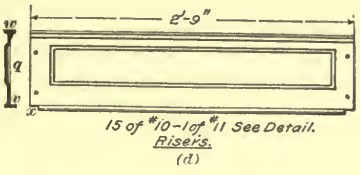


FIG. 14.

PLATFORM STAIRS.

18. The stairs shown in Fig. 15 is one of a series of flights that might be used from the basement to the top floor of a building wherein the stairs just described would be suitable in the basement. This flight represents the run between the third and fourth floors of a building as being typical of the whole stair system which is enclosed on three sides by a brick wall. In many respects the general construction is the same as in the previous example. The course to be pursued in laying out the stairs is the same as described for the previous case. The principal data to fix are (1) the size of the well; (2) the height of the story; (3) the number of risers and treads, with their height and width; and (4) the width of the stairs. The drawing is then laid out precisely as in the previous case, except that the

parts in this example are numbered in the order they will be required, as is usually done with working drawings, in order to facilitate the process of erection. These numbers are

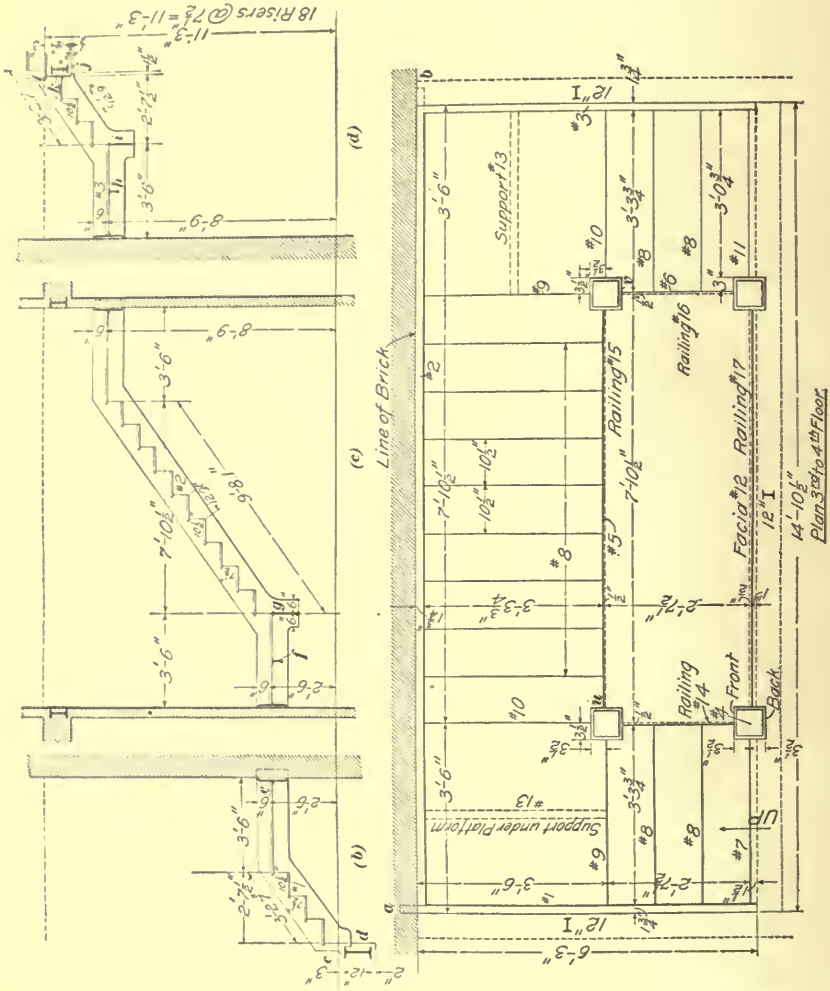


FIG. 13.

marked on the plans, when laying out the stairs; and the workman, by referring to the plan, finds, for instance, that # 1 indicates the wall string which must be first put in place.

He consequently looks for # *1*, and refers to each piece by its number instead of its name.

19. The holes indicated by the letters *a* and *b* on the plan (*a*), Fig. 15, are 4 inches deep for the reception of the ends of wall strings, and contain either an iron or a stone templet for the strings to bear upon. The wall string marked # *1* in the elevation (*b*) has a lug cast on the lower end *c*, through which it is bolted to the top of the beam *d*; at its upper end a lug *e*, which is shown in detail in Fig. 16 (*a*), is cast to receive the end of the string # *2* which supports the platform and the stairs on the wall side of the second run. String # *2* has two lugs *f* and *g* cast on the lower end; *f* to receive the light beam which carries the platform, and *g* to receive the end of the face string marked # *4* on the plan. The upper end of string # *2* has a lug, the same as that on # *1* at *e*, cast on it to receive the wall string # *3*. String # *3* also has on the lower part two lugs *h* and *i*; *h* to take a light beam to support the platform, and *i* to receive the face string # *5*. On the upper part of # *3* is cast a flange *j*, through which it is bolted to the beam *k*; there is also a small extension or easement *l* cast on this string to receive the case of the finish in the hallways. Provision for allowance or variation has been made at the floor ends of the strings # *1* and # *3*, as indicated.

20. The face string # *4*, as shown at (*a*), Fig. 16, is cast with the first two newel bases attached to it, the lower one of which has a lug cast on the back, as shown at *m* in Fig. 16 (*c*), which is a detail of the development of the base, through which it is bolted to the beam. This detail shows the base of the start newel developed flat so as to show all four sides. The back *a* is checked out at *n*, so that it may fit over the flange of the beam. The inside face of the newel *d*, against which the first riser must fit, has a lug *o*. The riser *p*, which also extends to form the facia *p'*, is bolted with countersunk screw bolts to the lug *o*. The front face of the newel *c* shows the section of the face string # *4* at *q*, and the

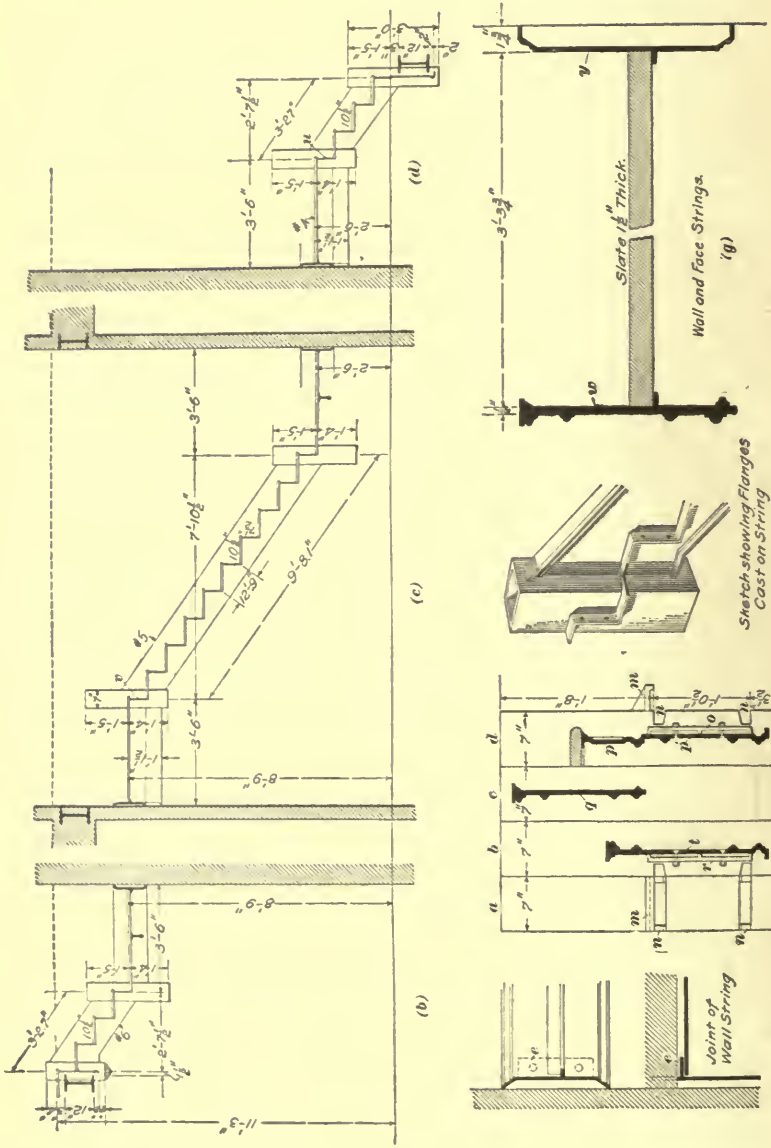

(d)
(c)
(b)
Slate 1/8" Thick.
Wall and Face Strings.
(g)
Sketch showing Flanges Cast on String
(f)
Development of Base of Newel at 3rd Floor Starn.
(e)
Joint of Wall String
(a)

FIG. 16.

outside of the newel *b* has a lug *r* to which the well facia *t* is bolted. The second newel base on string # *4* has a lug shown at *u*, Fig. 15 (*a*), cast on the outside to receive the end of the face string # *5*. The end of string # *4* is bolted to the lug *g* on wall string # *2* (see Fig. 15). The face string # *5* has the third newel base cast with it, and extends through to the wall string # *3*, to which it is bolted. The lower end is bolted to the lug *u* on the second newel base. On the third newel is cast a lug *v*, to which face string # *6* is bolted at its lower end. Face string # *6* has the base of the fourth newel cast on it, and the lugs are practically the same as those shown in the detail.

The next pieces which demand attention are the risers. It will be noticed, by referring to the plan (*a*), Fig. 15, that there are five different kinds of risers, and that each is indicated by a number commencing at seven and ending with eleven; these risers are the same as in the first example, and have been described, except those marked # *9*, which have a lug cast on the back at the center to carry the outer end of the light beam # *13*, which aids in the support of the platforms. The facia # *12*, a section of which is shown at *t* in Fig. 16 (*e*), has ribs cast 2 feet apart along the back to stiffen and support it, while clamps, which are bolted to the facia with countersunk screw bolts, are hooked over the beam. A detail, Fig. 16 (*f*), shows a perspective view of the string and base of the newel, with the flanges to receive the treads and risers. In the detail shown in Fig. 16 (*g*), *w* and *y* are sections of the face and wall strings, showing the moldings of each, the position of the slate treads, and the flanges supporting them. The railings include # *14*, # *15*, # *16*, and # *17*, shown in Fig. 15, and are the same as those described in Fig. 12. It often happens that it is necessary to introduce winding treads in

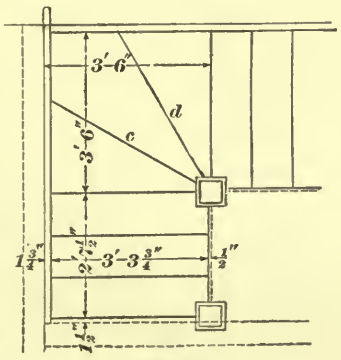


FIG. 17.

the angles, instead of straight platforms. For example, had the distance between the partitions in Fig. 15 been but 11 ft. 4½ in. instead of 14 ft. 10½ in., the treads might still have been kept 10½ inches in width by planning the corners as shown in Fig. 17. In this case the strings would take a curve which would be determined by the intersection of the treads and risers with the wall string; the elevation of these

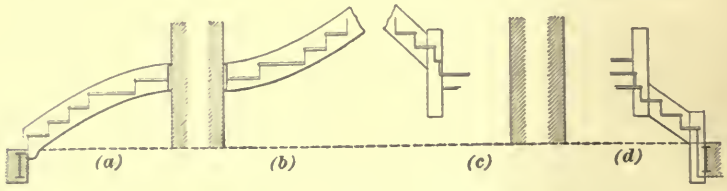
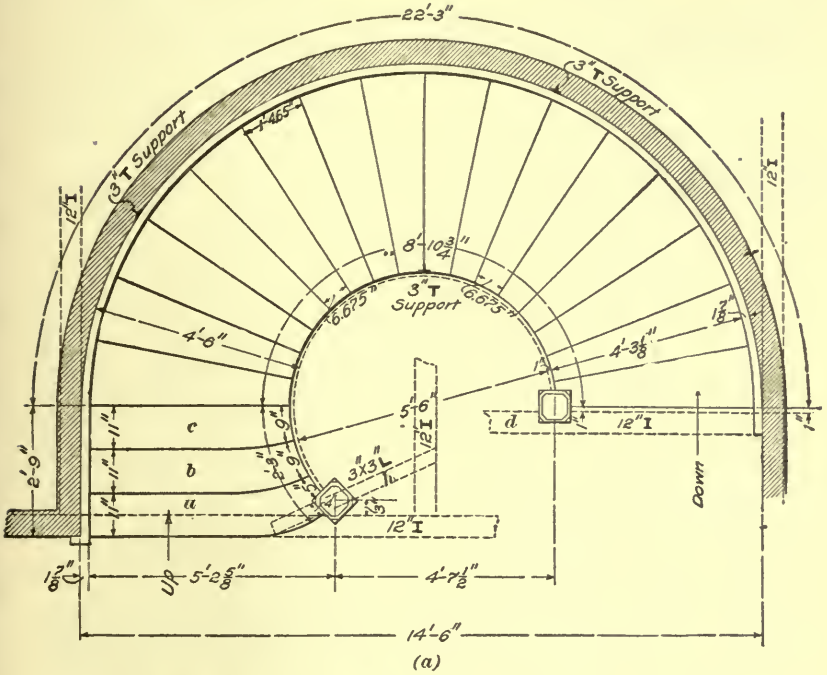


FIG. 18.

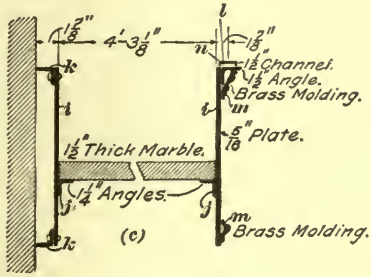
curves is shown in the section at (*a*) and (*b*), Fig. 18. The only other detail affected by the difference of conditions would be the increased length of the newels brought about by the winder risers *c* and *d* of Fig. 17, having their start at the newel, thereby lengthening it by their height, as shown in the section at (*c*) and (*d*), Fig. 18.

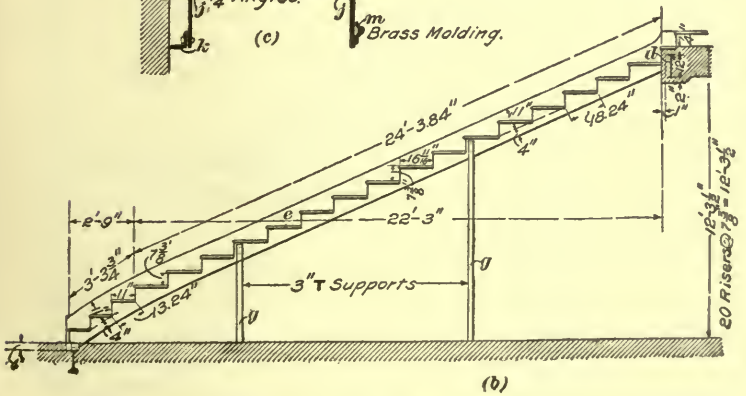
SEMICIRCULAR STAIRS.

21. In Fig. 19 is shown at (*a*) the plan of a semicircular stairway; while in Fig. 20 is shown the front elevation at (*a*), the development of the string at (*b*), and a detail of the rail on the upper landing at (*c*). The first three treads *a*, *b*, and *c* of the plan, Fig. 19, are 11 inches wide, and the remaining ones are so spaced as to be wider than this, if measured on a line midway between the strings. The diameter of the well hole is 14 ft. 6 in.; and, deducting twice the distance from the wall to the center of the treads, it will be found that the diameter of a circle drawn through the center of the flight is 9 ft. 11 in., or 119 inches, which, multiplied by 3.1416, will give for the circumference 373.85 inches. Dividing this by 2 and deducting from the result 1 inch (the distance from the top riser to the beam *d*) gives


22'-3"
3" T Support
3" T Support
1'-4½"
12" I
8'-10¾"
3" T Support
6'-6¾"
6'-6¾"
4'-6"
4'-3⅜"
1⅞"
5'-6"
12" I
d
12" I
c
b
a
3"x3"
Down
2'-9"
1⅞"
Up 5'-2⅝"
4'-7½"
14'-6"

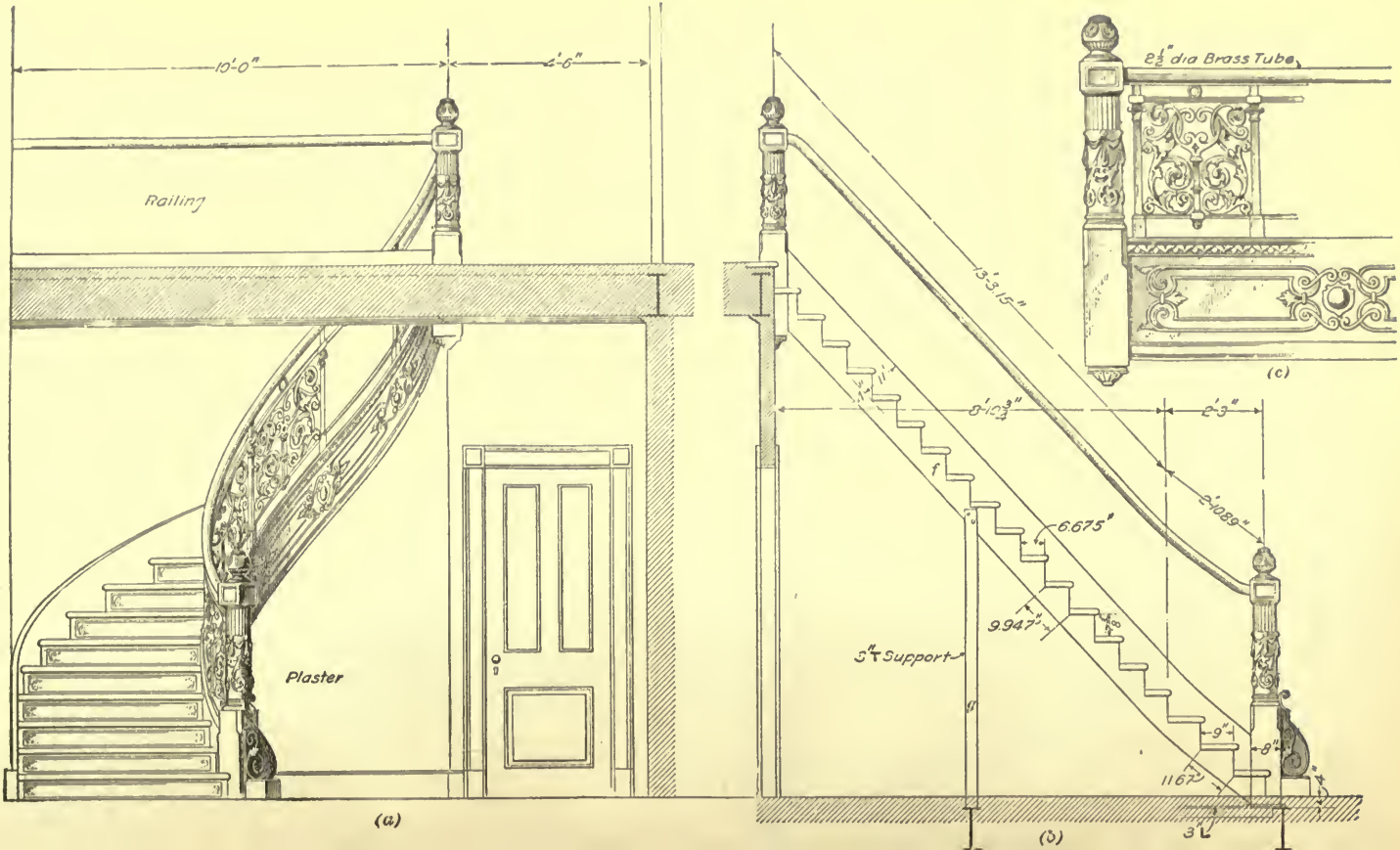
(a)


1⅞"
4'-3⅛"
1⅞"
1½ Channel.
½ Angle.
Brass Molding.
1½ Thick Marble.
⅝" Plate.
1¼ Angles.
Brass Molding.
(c)


24'-3.84"
48.24"
4"
2'-9"
22'-3"
3'-3¾"
13.24"
3" T Supports
20 Risers @ 7⅞" = 12'-3½"

(b)

FIG. 19.


10'-0"
2'-6"
Railing
Plaster
(a)
2½" dia Brass Tube
(c)
13'-3 15/16"
8'-10 3/4"
2'-3"
2'-10 89/96"
6.675"
9.947"
3"T Support
9"
8"
11.67"
3'-2"
(b)

the length of the center line required as 185.92 inches. This divided by the number of treads determines the width of each tread on that line to be $11\frac{5}{8}$ inches. The lengths of the strings around the outer and inner circumferences are taken on the inside faces, and determined in the same manner. In a stair of this character it is not possible to make sections through any particular part in such a way as to be of any service, but the development of each string is given instead.

22. To lay out a plan of such a flight of stairs as this, begin with the wall string and lay off from the foot of the flight the first three treads 11 inches wide, and the other sixteen will be 1 ft. $4\frac{11}{16}$ in., the latter dimension being found in the same manner as the width on the center line, and used in the development of the string, as shown at (*b*). A line drawn through the lower intersections of the treads and risers will form a basis from which to determine the width of the wall string, and to lay off the top and bottom lines of this string, as shown in Fig. 19 (*b*). The proportion of the treads to the risers in the short straight part of the string is 11 to $7\frac{3}{8}$, while that of the curved portion is $16\frac{11}{16}$ to $7\frac{3}{8}$, thus causing the string to take a different angle; the juncture of these two parts should be eased off, instead of showing the sharp angle, which would be out of harmony with a circular stair. This applies only to the wall string, as, in the development of the face string shown at *f* in Fig. 20 (*b*), we have a surface that is circular throughout its entire length. These circular strings are usually made of wrought-iron or steel plate, capable of being bent to the required curve, and this bending is done by hammering on a curved block if the material is light, or by mechanical pressure in case of heavy work.

23. With the exception of the straight part at the bottom of the wall string, both strings are helical in shape; that is, they take the form of a ribbon spirally wound around a cylinder and rising at a certain ratio.

To get this helical shape, the strings are first laid out flat, as shown in the developments, Figs. 19 (*b*) and 20 (*b*), with the lines of the treads and risers drawn on them; they are then laid across a block with the lines of the *risers* *a*, Fig. 21, parallel to the sides of the block, and, while in this position, are hammered or subjected to pressure every few inches. A wooden templet with one edge curved to the radius to which the string is to be bent is used to test the string and determine when it has been pressed to the proper curve. This templet is placed against the iron at short intervals, and held in a direction parallel to the lines of the *treads*. This bending may also be accomplished by passing the string through a set of rollers in an angular direction, provided the rollers are long enough; this method, however, is seldom used, in consequence of the great length of roller required.

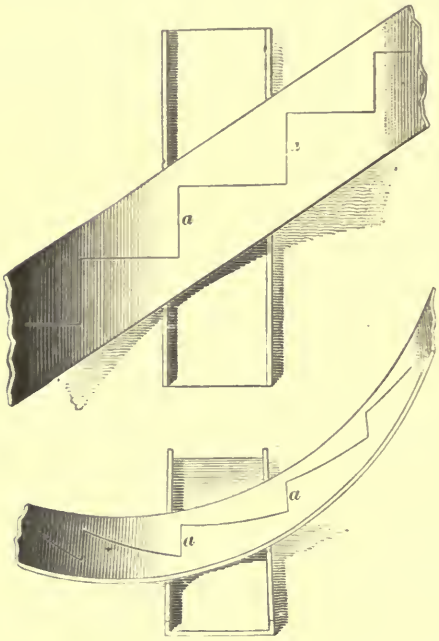


FIG. 21.

24. In making the pattern for the railing, it is advisable to first prepare a wooden drum of the same diameter as the stair well, on which the steps are laid out; and from them the top line of the string is obtained, which is also the bottom line of the railing. The top and any intermediate lines of the railing are then found by measuring perpendicularly from any point on the string line or from the center of each tread; and the whole railing may be either

modeled directly to the proper curve or made straight and bent to the curve afterwards. The well holes of all stairs are framed before the stairs are built, and in straight stairs there is little more required in the shape of structural support; in curved stairs, however, it is often necessary to introduce special supports, as has been done in this case by the upright T irons *g* shown in Figs. 19 (*b*) and 20 (*b*). The circular partition under the string in this case is of terra-cotta blocks, and is therefore incapable of affording sufficient support to the wall string. The strings should rest on the top of the floorbeams below, and be bolted to the webs of the floorbeams above wherever such is possible; but, as this cannot always be managed, bearings, such as shown at *h* in Fig. 19 (*a*), should be provided under the starting newel, and laid diagonally between the nearest beams.

25. The face string being of wrought iron, it must be bolted to the newel faces, and, in view of this, flanges are cast on the newel bases for this purpose. The constructive details for these stairs in the connections are the same as in Fig. 15 with the exception of the strings.

These strings are shown at *i* in Fig. 19 (*c*); the treads are supported on wrought-iron flanges *j* bolted to the string. The top and bottom flanges *k* of the wall string and the top flange *l* of the face string are of angle irons riveted to the string. The upper and lower edges of the face string are finished with brass moldings *m*, and the rail is first secured to the channel iron *n*, which in turn is bolted to the string.

CIRCULAR STAIRS.

26. A type of circular stairway, similar to that described on drawing plate entitled, Winding Stairs, in the section on *Architectural Drawing*, is shown in Fig. 22. This stair is suitable in some such position as an engine room, from a sidewalk to a subcellar, or from an attic to a dome or tower, or in any position where space is limited. The construction is of the simplest character, and consists of a central core or

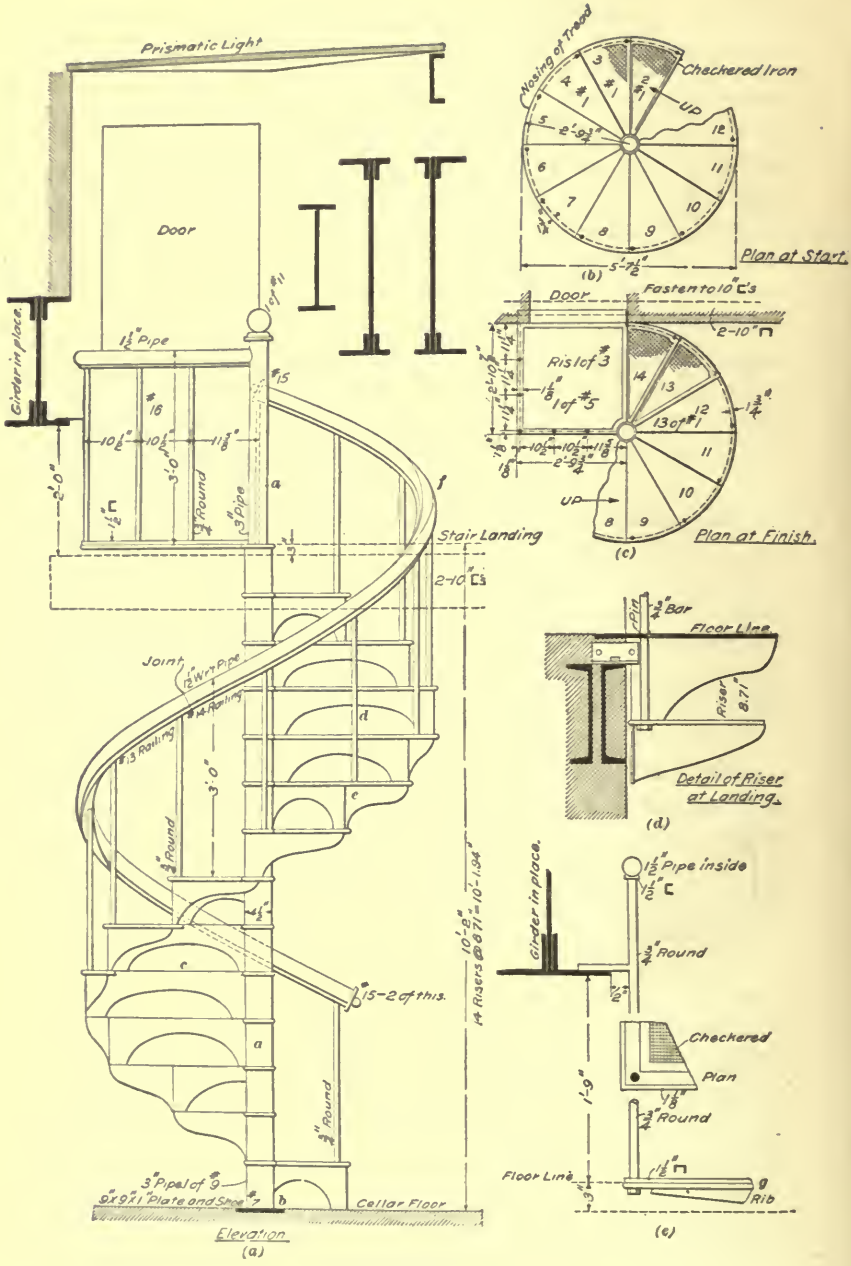

Prismatic Light
Door
Girder in place.
1½" Pipe
Stair Landing
Joint
12" Wrt Pipe
Elevation
(a)
Nosing of Tread
Checkered Iron
Plan at Start.
(b)
Fasten to 10" C's
Plan at Finish.
(c)
Floor Line
Detail of Riser at Landing.
(d)
1½" Pipe inside
Checkered
Plan
Floor Line
Rib
(e)

FIG. 22.

wrought-iron pipe *a* resting on a plate *b* at the bottom. The treads and risers *c* are of cast iron in one piece, with a collar to fit over the pipe *a*, so that in erecting the stair the risers and treads are slipped on as shown at Fig. 23. In order to keep them in place, the upright bars of the railing *d*, Fig. 22, are continued down through each tread near the front edge to a lug, or projection, *e* on the back of the tread immediately underneath, and secured with a nut. The top riser acts as a brace to hold the pipe in place, and is fastened to the beam with a wrought-iron strap of any suitable shape. There are no strings to be bent in this stair, but the hand rail *f* must be bent to the proper curve. This rail is composed of a small channel iron

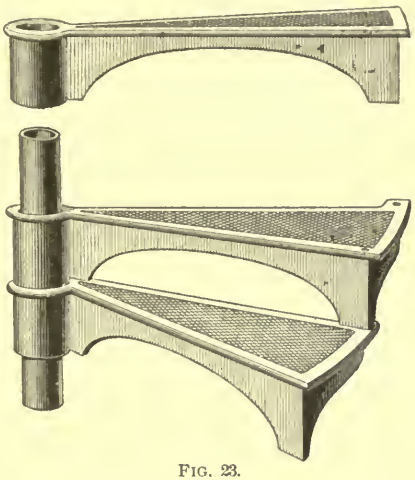


FIG. 23.

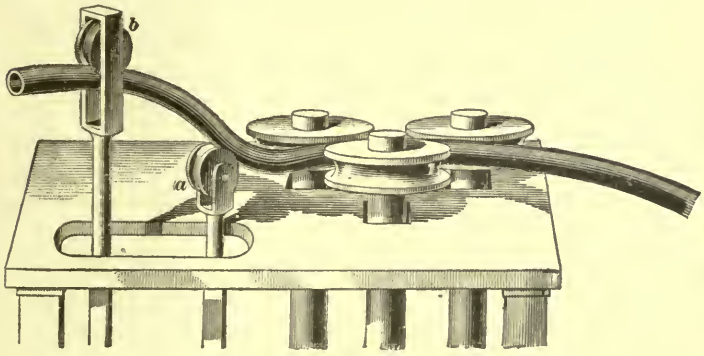


FIG. 24.

with a 1½-inch wrought-iron pipe on top. To bend any bar or pipe, the most satisfactory results are obtained by the use of rollers, preferably run by power, as shown in Fig. 24. one

of these rollers being capable of adjustment, so that the pipe or bar may be bent to any required radius. In this way, not only is it possible to give the hand rail the necessary curve, but, as the amount of rise per foot is known, it can be given this upward direction at the same time by setting the gauges, or guides, *a* and *b* to the proper angle. It is presumed the stair is erected before the hand rail is bent; and to determine if the rail has been bent to the proper curve, it is laid over the top of the steps, and corrected, if need be, by hand. It might, however, be required that the hand rail should be bent and set quite independently, and assuming that the rail were a flat bar, $1\frac{1}{2}$ in. $\times \frac{3}{8}$ in., it would be accomplished as follows: An end view of a tread and riser would be laid out in outline, the sizes being taken at the center line of the railing, as shown in Fig. 25 at *b*. A part plan of the stair, showing two treads, would then be drawn, as *e a* and *a f*, with a dotted line *c d*, through the points *e* and *f* where the tread lines intersect the outline of the stair plan. Then, from *a* as a center, and with a radius equal to *b* (which gives the upward rise for each step), arcs would be struck on the curve, the intersections of which, *g* and *h*, with the line *c d* would give points in the true curve of the rail. A circle described through the points *g*, *a*, *h* would give the curve to which the hand rail should be bent. The bar is then bent to this new radius and twisted evenly along the whole length of the stairs, in the manner and with the tools shown in Fig. 26. It will be found that the whole bar has now the form of a helix, and is of the required radius. Before being twisted, the positions

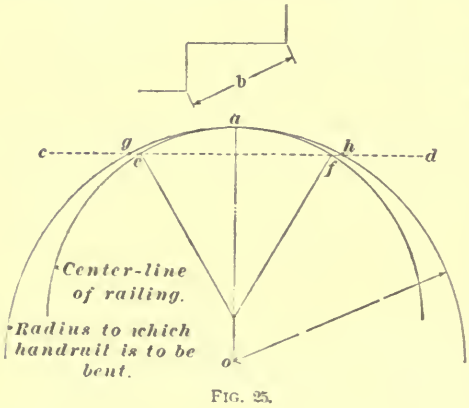


FIG. 25.

of the balusters should be marked on the bar, and the holes for them bored or punched, as the case may be.

At (*b*) and (*c*), Fig. 22, are two plans, one showing the start at the cellar-floor level, and the other the finish of the stairs

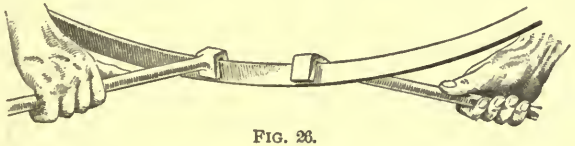


FIG. 26.

at the platform. The detail of the connection at the platform, and the method of securing the baluster through the

FIG. 27.

tread, and details showing the corner of the platform and the pipe forming the rail, are shown at (*d*) and (*e*). The platform is strengthened by the ribs *g* cast on the under side.

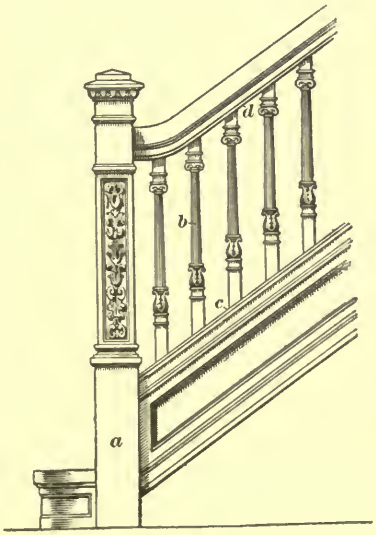


FIG. 28.

FRIEZES AND BALUSTRADES.

27. In Fig. 27 is shown a cast-iron frieze. The ornament is bold, and has considerable relief, but, being entirely on the surface, and not undercut, it does not present any special difficulty in molding, and the model may be withdrawn from the sand without injuring the ornament. The modeling of this frieze should be in clay, and then cast in

plaster, and the working mold cast from this last in the same material.

28. Figs. 28 and 29 are examples of stair balustrades or panels. Figs. 30 and 31 are examples suitable for exterior or exposed positions. The newel *a* in Fig. 28 is modeled,

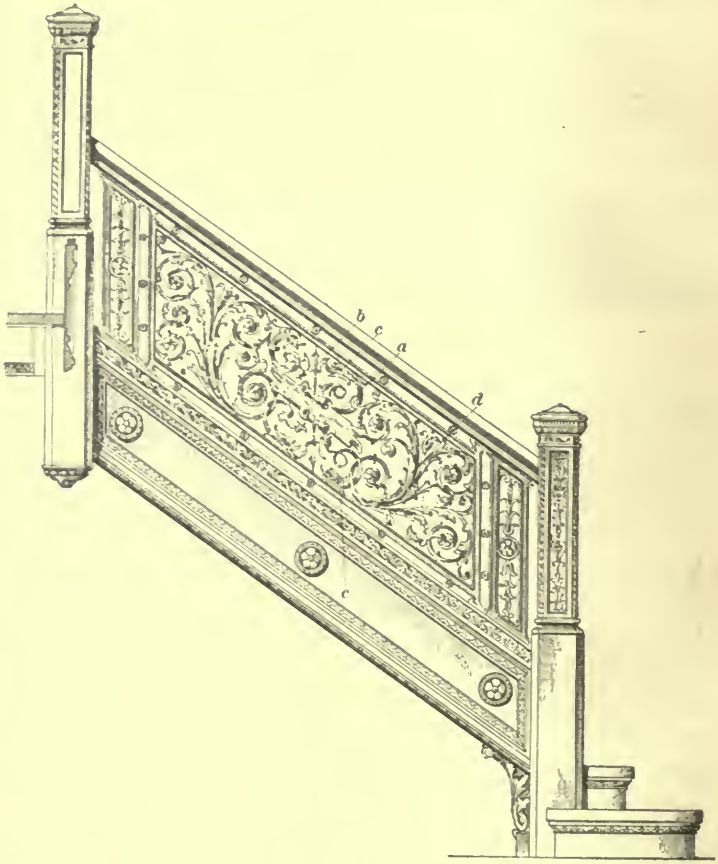


FIG. 29.

molded, cored, and cast in the same manner as the one before described. The balusters *b* are modeled in wood and cast *solid*. They are secured by countersunk tap bolts at the

bottom and top to an iron strap or rail *c* and *d* $\frac{1}{4}$ inch thick, and of width equal to the baluster base, or to a channel iron.

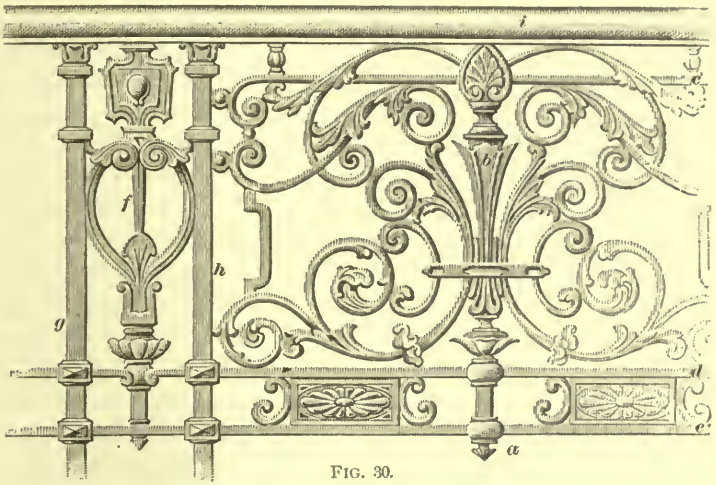


FIG. 30.

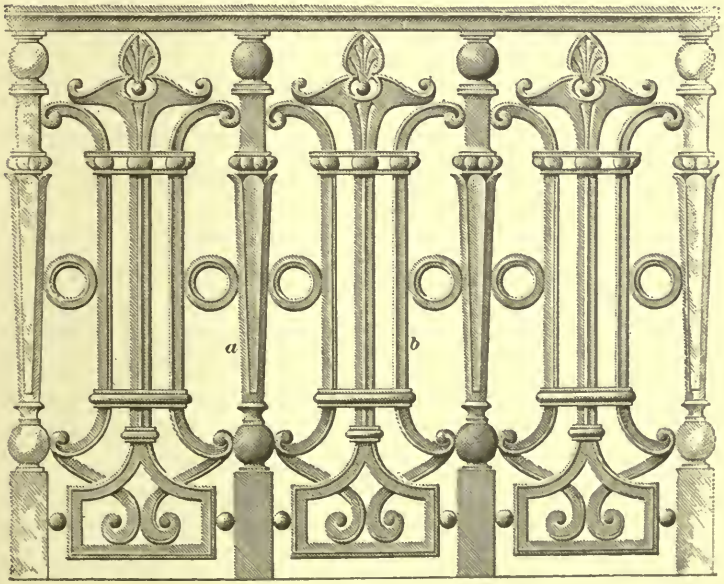


FIG. 31.

The characteristic features of the design shown in Fig. 29 are the cartouche *a* at the center of the panel, the trident *b* which pierces it, the dolphins *c* which act as supporters, and the scrolls *d* which complete a very rich and artistic panel. This design for a stair rail is especially good, as it fills the void between the string and rail, affording perfect protection, while at the same time the design is not overloaded with ornament, and is very well constructed.

The features of the railing shown at Fig. 30 are the long and short panels forming its divisions. The large panels *a* are strengthened and braced vertically at the middle, with a post *b* running from the top rail to the lower rail, and horizontally with the rails *c*, *d*, and *e*. The short panel *f* is let in between the posts *g* and *h*, combining them. The hand rail *i* is made of a brass or bronze pipe.

The rail at Fig. 31 is composed of a series of balusters *a* and panels *b* let in between them. The panel is well secured at four points on each side. The hand rail is formed of iron with a molded cap piece screwed on.

WROUGHT-IRON WORK.

METHODS OF MANUFACTURE.

CHARACTERISTICS.

29. **Wrought iron** differs from cast iron principally in the characteristics that it is soft, malleable, and fibrous, while the latter is hard, brittle, and crystalline, as explained in Art. **2.** This difference in character is due to the method of manufacture, as both kinds of material come originally from the same ore. Wrought iron is purer than cast iron, as the carbon, phosphorus, and sulphur are eliminated as far as possible, as well as other ingredients which abound in cast iron. It is the carbon which gives cast iron its hardness, and the phosphorus which makes it brittle, while the elimination of the sulphur renders wrought iron malleable

and capable of being forged. While it is practically impossible to entirely eliminate these ingredients in the manufacture of wrought iron, they may be so reduced as to be harmless. The presence of too much phosphorus will render the iron what is termed **cold short,** that is, brittle, or liable to split or break when hammered or bent cold. Sulphur, however, does not so much affect the cold working of the iron, but if present in excess it tends to make it **hot short,** or brittle at a red heat, and unweldable at any temperature.

The value of these characteristics will be better appreciated when the methods of working are described.

TOOLS AND IMPLEMENTS.

30. In some structural work, cast iron is used extensively on account of its cheapness; but for certain classes of work, cast iron is not suitable, and wrought iron is employed almost exclusively; as, for instance, the grille-work of elevator enclosures, light railings, lamp brackets, and work of a like character.

Ornamental wrought-iron work may be divided into two general classes; namely, that which requires to be fashioned while hot, and lighter work which is manufactured from cold materials. In each case the original material is in the same form—long bars of varying widths and thicknesses, which are worked with vise and pliers, are forged with hammer and anvil into any desired shape. The dominating feature of some designs is frequently the repetition of similar scrolls or rings; and when there are a number of these, it is necessary that they should be produced rapidly and exactly alike. In making any small scroll of light iron, the first and most important step is the forming of the small quirk, or curl, at the center, and the method and machine for doing this is shown in Figs. 32 and 33. The tool employed is of a very simple character, and consists of a fixed cam *a*, over which the clamp, or die, *b* fits closely and is pivoted at the other end; the spring *c* keeps the die clear of the cam, and the lever *d* forces it into place. In Fig. 32 the lever is

thrown back to allow the clamp to be pressed open by the spring *c*. The bar, the end of which is to be bent, is introduced between the cam *a* and the clamp *b*. The lever is

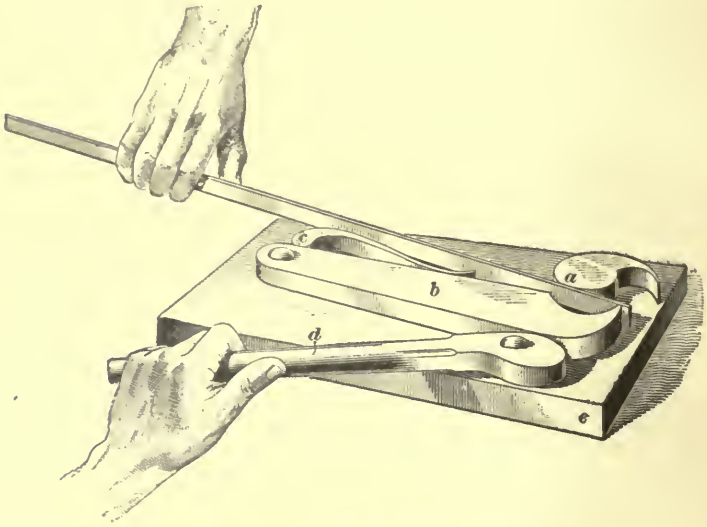


FIG. 32.

then pulled forward, and the die is forced against the cam, and the beginning of the scroll is formed. The bar is then

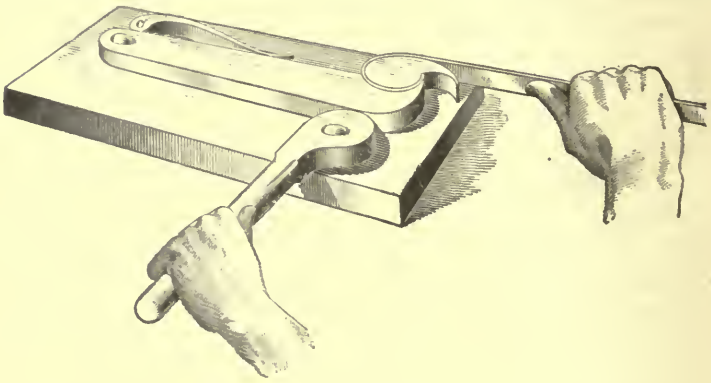


FIG. 33.

brought around to the position shown in Fig. 33, and the first convolution of the spiral thus completed.

31. The bar is now placed in the machine shown in Fig. 34, and the remainder of the scroll is formed. This machine consists of a shaft *a*, on which a screw thread is cut, and over which is coiled a steel spring *b*. On one end of the shaft is a crank or handle, and on the other end is the disk *e*

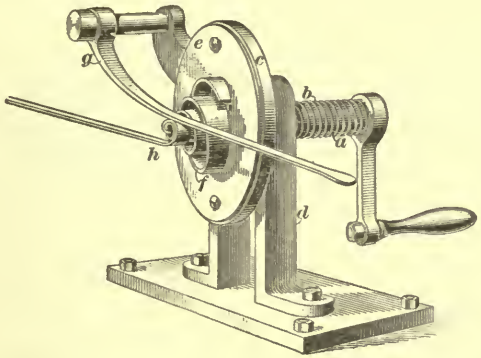


FIG. 34.

carrying the coil or volute *f*, which forms the die or pattern for the rest of the scroll. This plate and volute are detachable, so that different sizes of scrolls may be formed on the same machine.

The bar, having had the first convolution of the scroll formed as already described, is now placed in the machine, as shown at *h*. The lever *g* is pressed against it to hold it in close contact with the volute *f*, and the disk is revolved until the scroll has assumed the proper number of convolutions. As the shaft turns, the screw thread causes the disk to advance, and the bar *h* is coiled evenly in one plane, instead of conically, as might appear from the spiral on the disk. When the shaft has reached the point where the proper number of revolutions has been attained, a catch releases the nut from the screw thread, and the spring *b* throws the shaft and disk back to their original positions, and releases the completed scroll, which is now cut off the bar, and another one prepared in the same manner. With such appliances one man can make from 300 to 600 scrolls a day, according to their size and weight; but where only a few

are required it is usual to make them almost entirely by hand, for which tools similar to those shown in Fig. 35 are

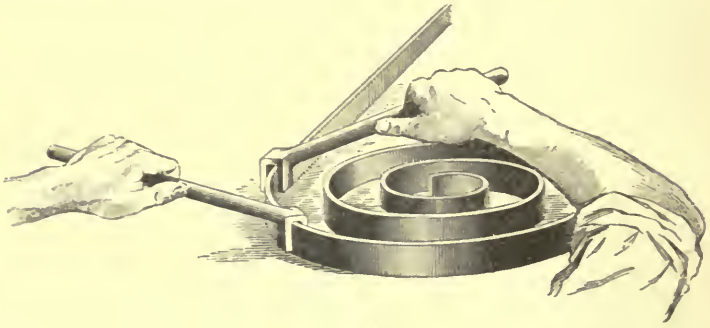


FIG. 35.

used, the operation being so simple that description is not necessary.

32. As it is more economical to have special machines for the manufacture of scrolls in quantities, the same applies to the twisting of flat bars, and for this purpose the appliance shown in Fig. 36 is used. This apparatus consists of a

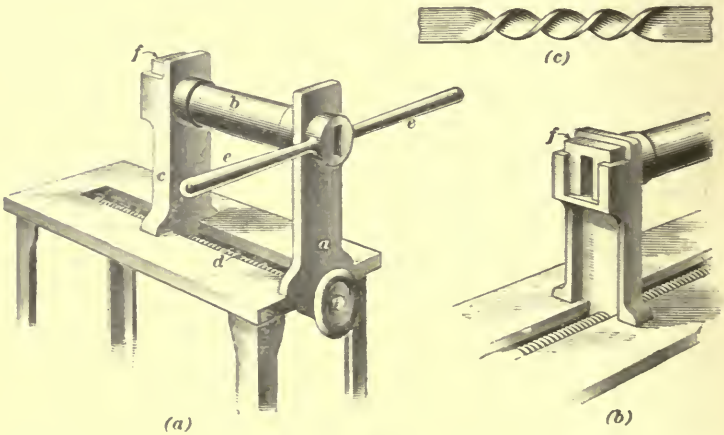


FIG. 36.

fixed upright *a*, with a socket to receive the pipe *b*, the other end of which rests in the movable upright *c*. The latter is arranged to travel along the bedplate by means of a threaded

shaft *d*, so that the length of the pipe *b* may be changed to suit the length of the twist required to be produced. The bar to be twisted is passed through the pipe and the slot in the lever *e* until in proper position, and the slotted piece *f* is dropped into the pocket, as shown at (*b*). If the length of the pipe is such that the distance between the lever and the slotted piece is of the desired length for the twist, then the bar being held at these two points and prevented from revolving independently, the lever is wound around as many times as is necessary to produce the required twist. The greater the number of turns, the closer will be the twist. The piece *f* is made loose and dropped into place, so that it may be easily lifted out when the twist is complete, and the finished bar drawn out without twisting it through the slot, as would be necessary if the slots were permanently fixed in each end. The pipe *b* merely acts as a guide to prevent the bar from bending in a lateral direction when the twist is of considerable length.

33. This machine is for making a regular twist, as shown at (*c*), but another form of twist in common use, especially

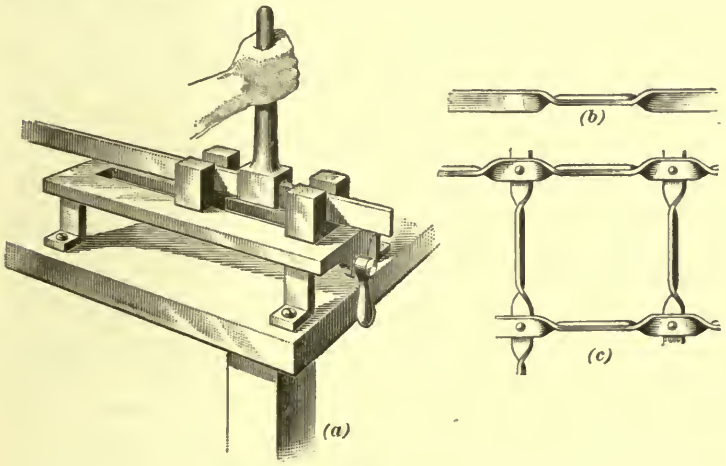


FIG. 37.

in light grille-work, is made by giving the bar a series of half turns, as shown in Fig. 37. The bar is dropped into

two slots, as shown, one of which can be adjusted by means of a long screw underneath the bedplate, so that the length of the part to be twisted may be regulated. It is then grasped between these slots by the loose clutch, and given a half turn, producing the result shown at (*b*). If the bar is to form a part of a square mesh grille, as shown at (*c*), there will be a number of these twists to each piece, and the distance from center to center must be marked out before the twisting is commenced. If the quantity required should be great, it might be advantageous to make a set of fixed pockets set to the proper centers, so that six or more turns could be made without lifting the bar. The foregoing are a few of the tools used in the manufacture of light grille-work; where, however, this class of work is produced to any great extent, there is a constant demand for new tools to meet the requirements of special conditions, but these tools cannot be bought and must be made. It would be impossible to provide for the manifold variations that are likely to occur; but, apart from these special tools, those that are here illustrated are always in demand, and supplement the general machines, such as drills, punches, lathes, etc.

34. Grilles.—Having described the tools used in working wrought-iron bars into forms from grilles, a few examples of the simpler forms of grilles are shown at Figs. 38 to

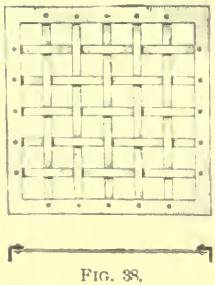


FIG. 38.

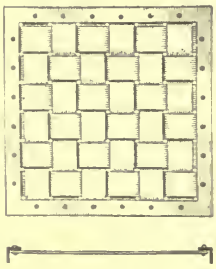


FIG. 39.

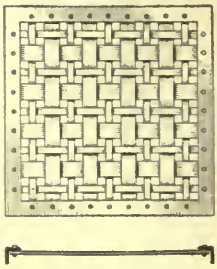


FIG. 40.

41. These are plain basket patterns, and can be made in any size iron and set to any mesh. The frame is of angle iron, the ends of the meshwork being riveted to it. The

meshwork grilles, being of an interlaced pattern, form a strong and economical screen to manufacture. If the surface to be screened by this basketwork is considerable, it is desirable to run a line of rivets at intervals through the mesh;

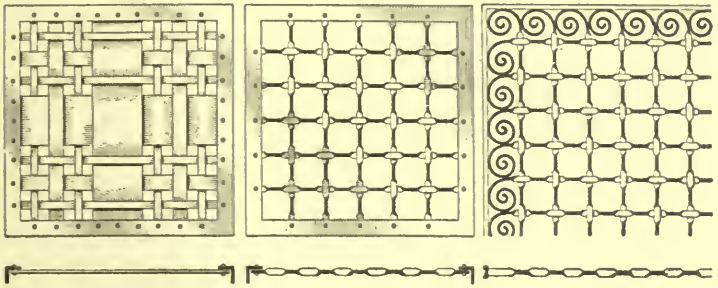


FIG. 41. FIG. 42. FIG. 43.

otherwise, the metal strips that form the mesh are likely to slip out of place and become distorted. If a more ornamental grille is wanted, the simplest variation is secured by twisting the bars as shown in Fig. 42, the result being that

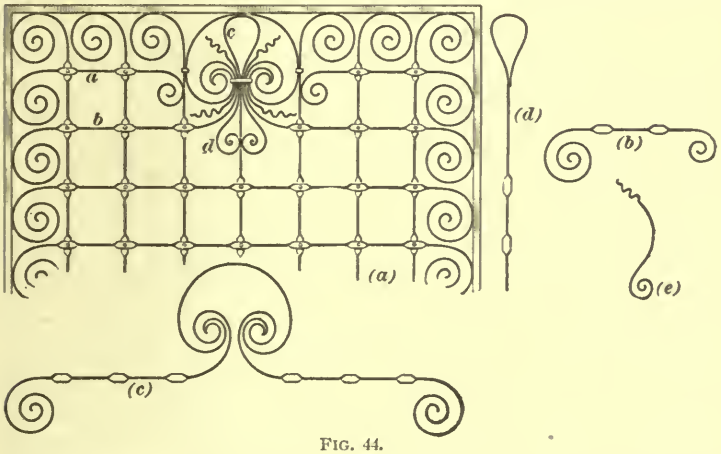


FIG. 44.

a mesh is produced with the edges towards the eye and a series of flat crosses at the intersections. If a border to the grille is desired, the scroll ornament shown in Fig. 43 is suitable and inexpensive. A glance at the illustration will

show how this is made, by turning the ends of each strip or bar. In this case an angle-iron frame could not very well be used, because part of the scroll would be hidden by the flange of the angle. The frame may be a flat bar, though a small channel would be preferable, as the ends of the rivets that fasten the scrolls could be hidden in the hollow of the channel.

35. A great variety of grille designs have the square meshwork shown in Fig. 42 as a basis, with additional ornament introduced at top and bottom, as shown in Fig. 44, or with a border and center ornament, as in Fig. 45. It will be seen that the ornament is formed to a great extent by

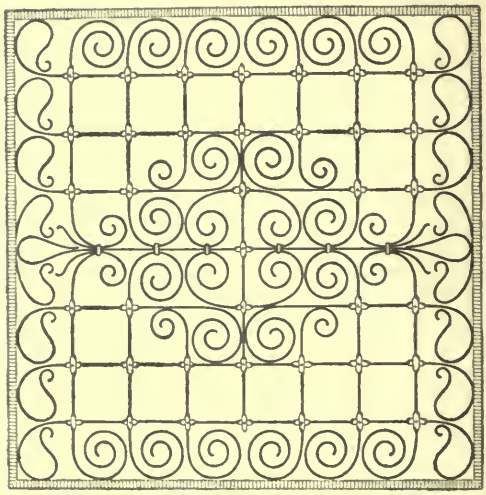


FIG. 45.

turning the ends of the bars forming the square meshwork into scrolls, and adding other scrolls as may be desired. This can readily be seen by examining the designs shown, but to make it perfectly clear, some of the component parts of Fig. 44 are shown separately. The small top scroll *a* is shown separately at (*b*); the large central scroll *b* is shown at (*c*); the central division and loop *c* is shown at (*d*); and the small scroll and ribbon *d* is shown at (*e*). These are all made of single pieces

of iron. The pattern shown in Fig. 46 is designed to produce a diaper effect, as is also Fig. 47, the latter being a

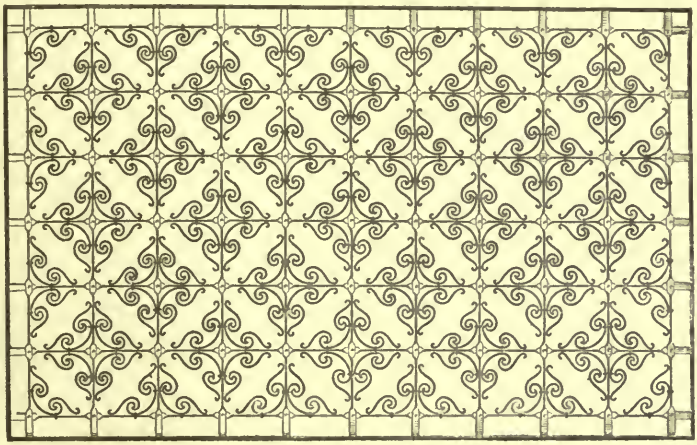


FIG. 46.

more open pattern. These designs are all for grilles of light strips not over $\frac{1}{16}$ inch thick by $\frac{5}{16}$ inch wide, though at times

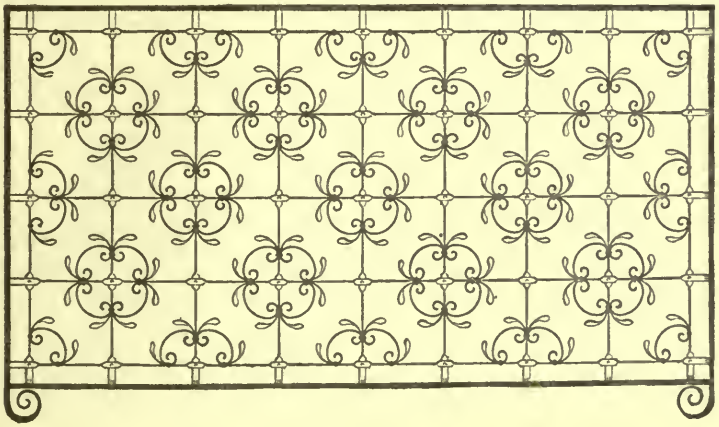


FIG. 47.

heavier material may be employed. Figs. 48 and 49 are radiating designs suitable for arched window or door

openings, but in other respects are precisely the same as the above described. At Figs. 50 and 51 the square mesh is

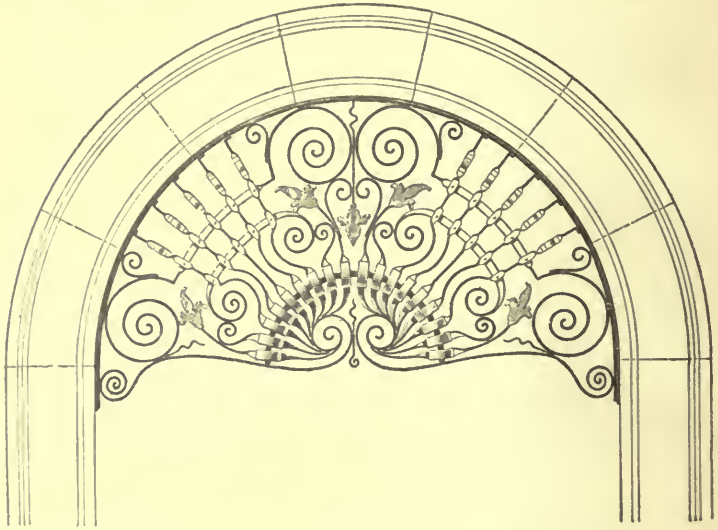


FIG. 48.

abandoned, and the metal is made rather heavier, so that the long straight bars may be strong enough to resist the tend-

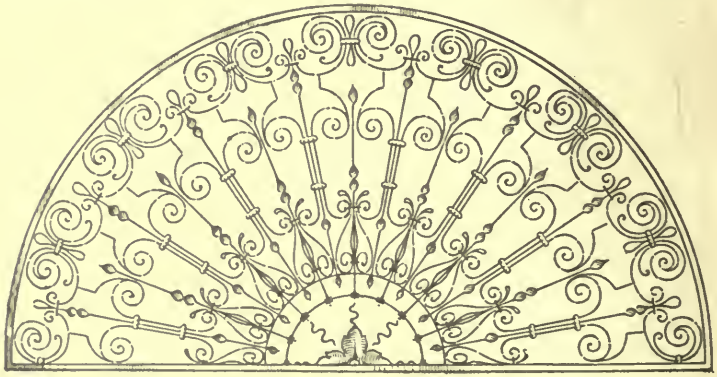


FIG. 49.

ency to bend. There is no set rule for determining the size of iron of which a design should be composed, as this is

governed by considerations of artistic fitness for the position for which it has been designed. If the iron is too thick to be

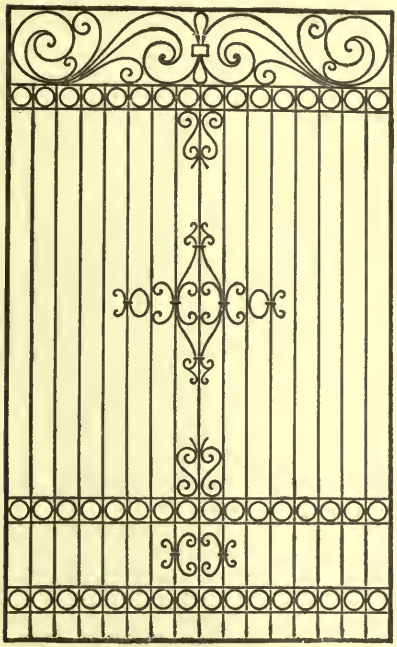


FIG. 50.

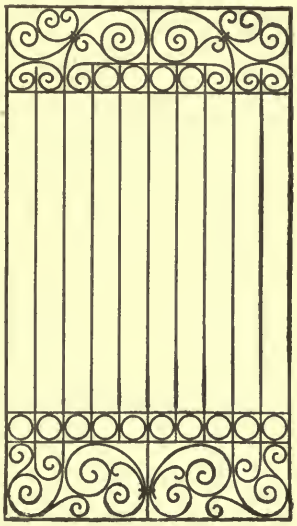


FIG. 51.

readily twisted at the intersection, it may be half checked, as shown in Fig. 52; or, if one piece is wider than the other, the wide piece may be punched out to permit the narrower one to pass through it, as shown in Fig. 53.

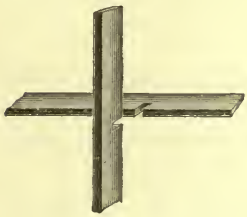


FIG. 52.

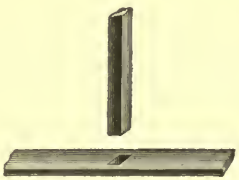


FIG. 53.

OFFICE GRILLES.

36. The metal counter rails in banking houses, offices, etc., so far as the grille-work is concerned, are in no way different from the grilles heretofore described; but the

arrangement of the supports, and the height and division of the rail, must all be proportioned to suit the special conditions of each case. Figs. 54 and 55 are examples of grilles made of cast and wrought iron. In Fig. 54 the rail and the posts are of cast iron, but the frame of the grille and the wicket gate and frame are of wrought iron. The grille is a simple basket pattern of ribbon iron twisted at the intersections and

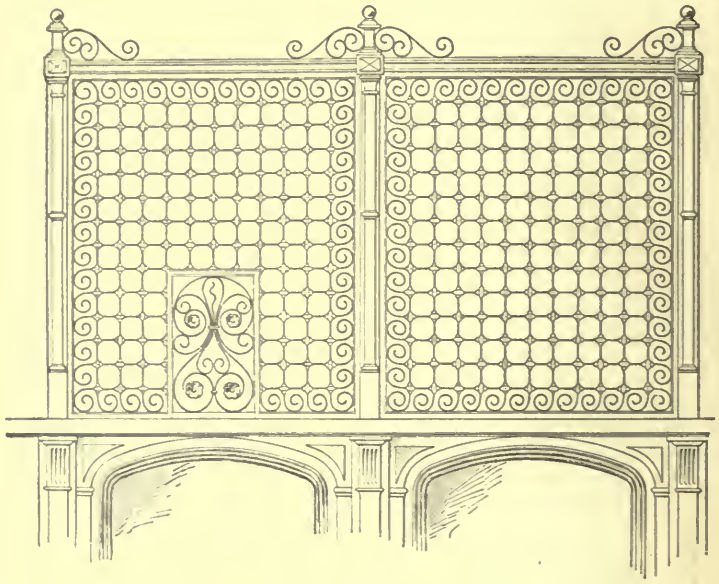


FIG. 54.

wrought into scrolls at the outside to form a border. The main scrolls of the wicket are finished with cast-iron rosettes. The rail has a cresting produced by extending the post with a finial ornament, and placing a scroll each side of it.

The design shown in Fig. 55 is more elaborate. The posts and rails are of cast iron, as in the former case, as well as the frame surrounding the wicket gate; but the entire screen is backed up with plate glass. The posts have a fluted band above the base, and just above this is a band or circlet to carry out the line of the baluster rail of the screen. The entire grille of each panel is set in one frame, which is

divided into two parts, the lower part forming a balustrade design, and the upper part a diaper; the loop scrolls of the diaper are ornamented with a pendant of leaves, as shown. The frame is separated from the rail, counter, and sides, by button washers, as shown. The plate-glass panels back of the screen are set in an angle-iron frame fitted with hinges, and swinging inwards so that they may be opened to clean

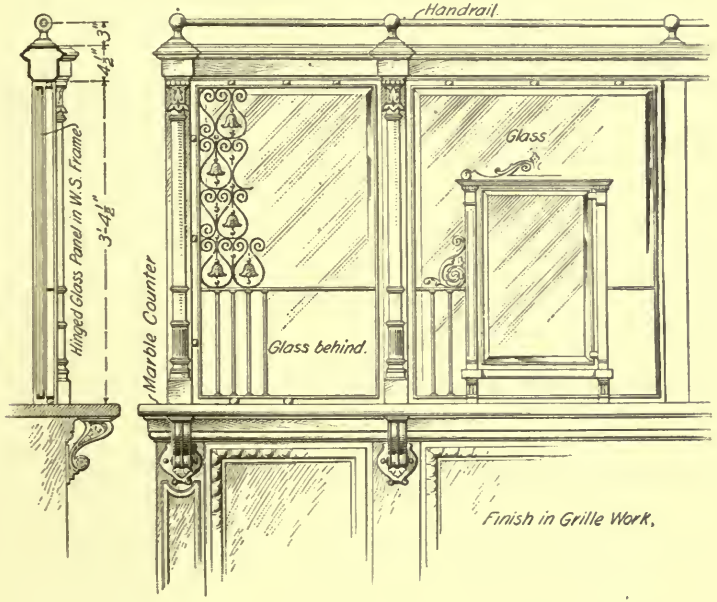
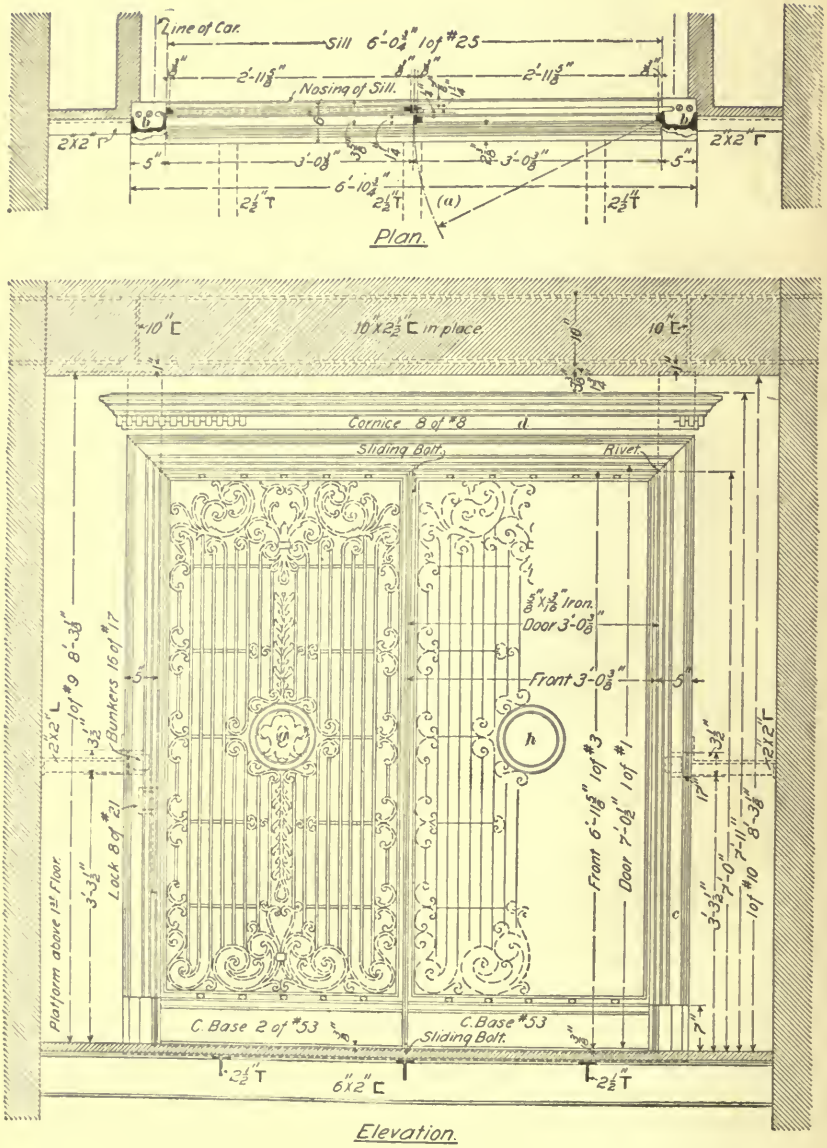


FIG. 55.

the glass. The wicket frame is designed with architraves and lintel, as would be any door or window. The change shelf under the wicket is of polished metal supported on two console brackets. The head of the opening is ornamented with a cast-iron scroll and leaf, but the scroll at the junction of the frame and the baluster rail is of wrought iron, and is placed there to give rigidity to that point.

The moldings of the rail at the top of the screen are broken out over the posts to emphasize the divisions of the screen. Over each of these points is a finial ornament, which also serves as a standard through which the brass upper rail


Line of Car.
Sill 6'-0¾" l of #25
2'-11⅝"
2'-11⅝"
Nosing of Sill.
2X2" ⌐
2X2" ⌐
5"
3'-0⅛"
3'-0⅛"
5"
6'-10¼"
2½" T
2½" T
(a)
2½" T
Plan.
10" ⊏
10"X2½" ⊏ in place
10" ⊏
Cornice 8 of #8
Sliding Bolt.
Rivet.
⅝"X⅜" Iron.
Door 3'-0⅛"
Front 3'-0⅜"
5"
2X2" L
10l #9 8'-3½"
3½"
Bunkers 16 of #17
Lock 8 of #21
3'-3½"
Platform above 1st Floor.
Front 6'-11⅝" l of #3
Door 2'-0½" l of #1
11"
3½"
2X2" ⌐
3'-3½"
2'-0"
2'-11"
10l #10 8'-3½"
C. Base 2 of #53
C. Base #53
Sliding Bolt.
2½" T
6"X2" ⊏
2½" T
Elevation.

(b)

FIG. 56.

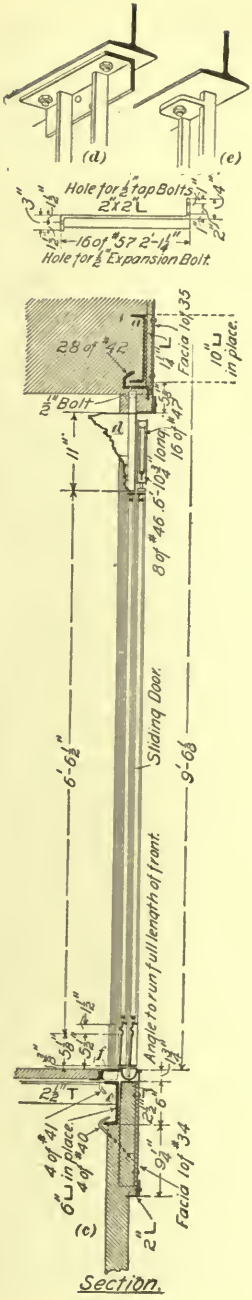

(d)
(e)
Hole for ½" top Bolts
2"x2"L
16 of "37 2'-1¼"
Hole for ½" Expansion Bolt.
28 of "42
Facia 1 of 35
10"L in place.
⅝" Bolt
16 of "43
8 of "46 6'-10¾" long
11"
6'-6½"
9'-6¾"
Sliding Door.
Angle to run full length of front.
2½" T
4 of "41
4 of "40
6"L in place.
Facia 1 of "34
2"L
(c)
Section.

FIG. 56.

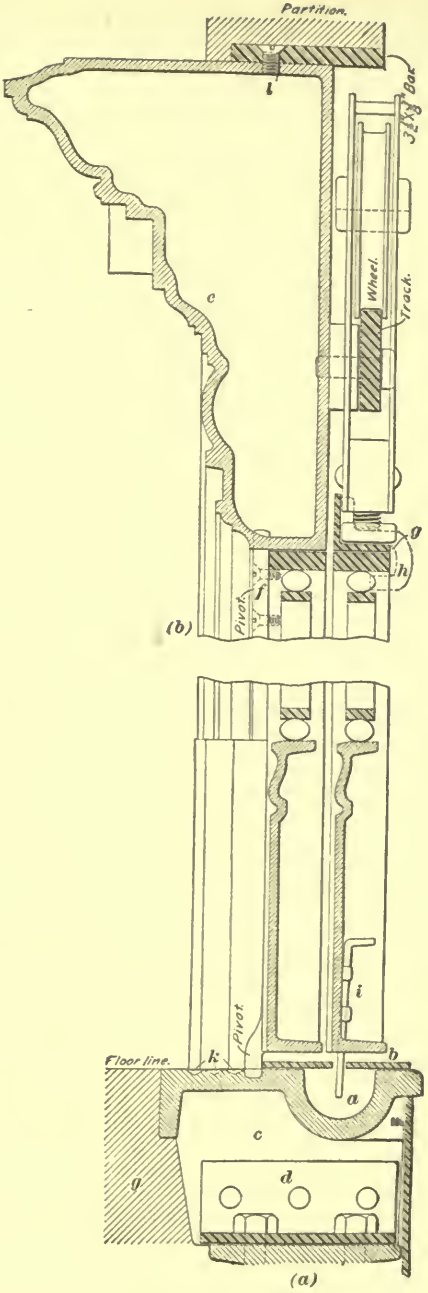

Partition.
3½"x3" Bar
Wheel.
Track.
(b)
Pivot.
Floor line.
Pivot.
(a)

FIG. 57.

passes. These examples represent the usual forms and outline of this class of work, but the details of the design will vary with each individual case.

ELEVATOR ENCLOSURES.

37. All the preceding examples of grille-work are suitable for use in elevator enclosures or any similar screen work, and their application to such work will now be considered. In Fig. 56 is shown an example of grille-work front for an elevator shaft. The shaft is formed by the main wall of the building in the rear, and fireproof partitions on the sides, the front only being of grille-work. An angle iron or a channel is usually set across the front of the well at each floor, as shown at *a*, Fig. 56 (*c*), the top of which is generally 4 inches below the level of the finished floor of the story above, although the location of these beams, being a matter that is determined in connection with the general structural framework of the building, varies materially in different structures. The enclosure work must, of course, be made to suit the positions of these beams on which it is supported, and the important point is their relation to the finished floor level. In fact, the principal measurements necessary to lay out the work are the width between the partitions, the distance from the finished floor to the top of the beams, the depth of the beams, and the height from floor to floor (which will generally be the same as from beam to beam). Having these points determined, the position of the cast-iron jambs shown at *b* in the plan (*a*) should be fixed. In this example the whole opening is surrounded with a cast-iron architrave *c* consisting of the jambs shown at *b* in the plan, over which is set the cornice *d*, standing independent and distinct from the partition. The jambs rest on top of the steel channel shown at *e* in the section (*c*), and are bolted to it at the bottom; while the top is run up and bolted to the bottom of the channel *a*, as the partition itself affords no support. The upper portion of the jamb is checked back from the point where the architrave is mitered, to the bottom of the beam

above, in order to permit the cornice to pass in front of it, and to permit it to be enclosed in the partition. The top connections may be made by riveting to the head of the jamb a short piece of angle iron, to project each side of the jamb, as shown at (*d*); or, the top of the jamb may be cast with a flange or lug about ½ inch down from the top, as shown at (*e*). The half-inch clearance permits the jamb to be shortened a trifle if necessary, when fitted to its position.

The jambs being set perfectly plumb, the sill *f* is then put down, and, as will be seen in the section (*c*), the edge next to the floor is turned down about 1½ inches, to form a flat surface for the woodwork to finish against. The angular grooves shown at *k* in the large detail of the sill, Fig. 57 (*a*), give a better foothold than if the surface were smooth; the deep groove *a* in the same detail is for the bottom guide of the sliding door to travel in, and is made ample in width, and closed in on each side with a strip of wrought iron *b*, to permit of adjustment in case the cast sill is not set true. The wrought-iron plates are also advantageous, inasmuch as they serve better to keep the door in its proper place and reduce the friction surface to the narrow edges of the strips only. As the side of the sill next the shaft is not deep enough to reach to the beam, upright ribs *c* are cast about 3 feet apart along the under side; and on one side of each of these ribs is riveted a piece of angle iron *d*, which is bolted to the beam. The cornice is a hollow casting, as shown at (*b*). It is open at the ends where the extensions of the side jambs pass behind it, and it is mitered at the corners where it joins and is bolted to the jambs and architrave with countersunk screw bolts. The cornice is secured to a bar with screw bolts, as shown at *l*, and the bar in turn is bolted at each end to the jamb.

38. In Fig. 58 is shown a plan and horizontal section of the front of the enclosure. The strap brackets *a* are of 2″×2″ angle iron, and are so placed as to brace the opening laterally. They are bolted to the structural column with expansion bolts, and to the architrave with countersunk screw

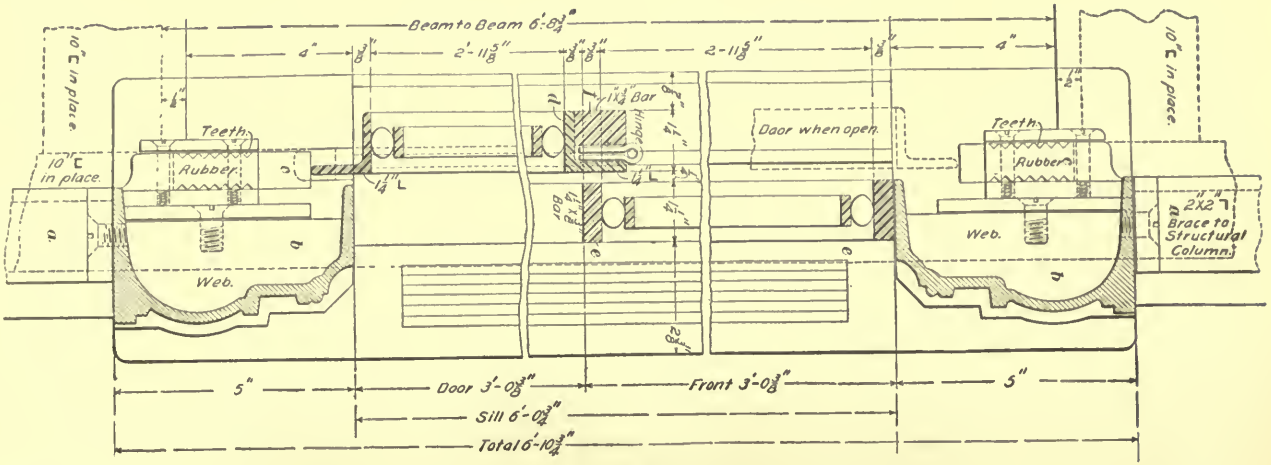

Beam to Beam 6'-8¾"
4"
2'-11⅝"
2'-11⅝"
4"
10"C in place.
10"C in place.
Teeth
Rubber
Web.
1¼" Bar
Hinge
Door when open.
Teeth
Rubber
Web.
2x2 Brace to Structural Column
5"
Door 3'-0⅜"
Front 3'-0⅜"
5"
Sill 6'-0⅝"
Total 6'-10¾"

FIG. 58.

bolts. The webs *b* of the architrave are sufficiently thick to provide the tap or screw bolts securing the door stop a firm and sufficient hold. These stops are fitted with a rubber cushion *c*, which takes up the recoil and noise of the door when operated.

By referring to the elevation (*b*), Fig. 56, it will be observed that the grille-work is divided into two large panels, one being the door *g*, and the other a pivoted panel *h*. The frame of the door is composed of angle irons, as shown at *d*, Fig. 58, and the frame of the pivoted panel of flat bars, as shown at *e*. The pivots are secured to these bars with screw

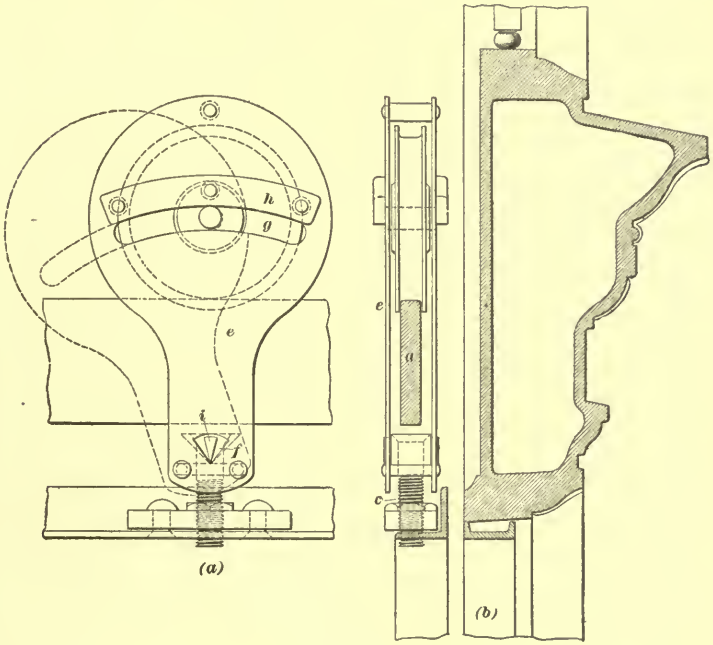


FIG. 59.

bolts, as shown at *f* in Fig. 57. On the sliding door is a bar shown at *f*, Fig. 58, to which the door is hinged. The bottom of this bar carries a guide, fitting in the groove of the track, and at the top secured to the angle iron *g*, Fig. 57, which is a slight extension of the door frame. The door is held in

place by the guide bolt *i*, and the panel by sliding bolts. The reason for this arrangement is to facilitate and make possible the entrance to the elevator of large pieces of furniture; in such a case, the whole front may be swung open by first drawing the sliding bolts in the pivoted panel, then drawing the guide bolts and pushing back the sliding door to its full extent. Both sections are then swung open, the bar and the angle iron remaining attached to the hinges. When used under ordinary conditions, the sliding door is held in place and firmly attached to the hanger by the clips shown dotted at *h*.

39. The hanger consists primarily of a pair of wheels running on a track, from which the door is suspended. These wheels are both alike and are set about 12 inches from each end of the door, the position varying somewhat in different doors. Fig. 59 shows the principal features of this hanger, which is patented. The track *a* shown in the section (*b*), on which the wheels run, is fixed to the back of the transom at each end by cast-iron supporters *b*, shown in detail in Fig. 60, which should be set perfectly level. The track, with the wheels on it, is then put in position, and the bolts *b'* are loosely screwed through the slotted holes in the end. If it is found necessary to further adjust the track, the screws *c* are for that purpose, so that it can be easily set level; then the bolts *b'* are to be screwed up tight. On the arrangement of the sides which enclose the wheels depends the easy gliding

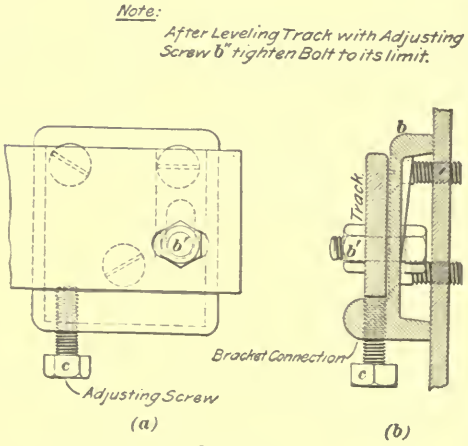


FIG. 60.

motion. These sides *e*, Fig. 59, are punched out of solid steel. At the lower end there is a **V**-shaped hole *f* and across the center is a slot *g* reinforced by a steel strap *h* in which the axle of the wheel travels and revolves. The slot is an arc of a circle whose center is the lower angle of the **V**-shaped hole, and the door is suspended from the knife-edge bearings *i* resting in this **V**. When the door is at rest the wheel is in the position shown by the full lines, and as it is pushed along the sheaves gradually swing over to the position shown by the dotted lines, the center of the wheel always remaining over the point of suspension. This prevents any rubbing motion at any point, as the axle of the wheel is not bound in any way, but simply rolls in the slot, and it is evident that the friction at the point from which the door hangs is practically nothing. If it is found necessary to raise or lower the door itself, this may be done, after everything is in position, by turning the suspending bolts *c*, which are squared at the neck to afford a hold for a key or wrench.

40. The construction of the enclosure, as well as the design shown in Fig. 61, differs considerably from that of the preceding example. With the exception of three details, it is entirely of wrought iron, these exceptions being the sill, the transom, and the molding at the top of the lower panels. By referring to the plan (*a*) of the small scale detail, Fig. 62, also the section (*d*), the surroundings governing the design may readily be seen. The main support of the screen is a round bar or column, shown at *a*, Fig. 61, which consists of a wrought-iron pipe $2\frac{1}{2}$ inches in diameter fitted with a cap and base. The top is secured to the soffit of the brick arch over the partition with an expansion bolt, and also to the cast-iron sill at the floor level. The grille screen is separated from this column by a small post *b*, which forms the sides of the grille frame and is finished with base and finial. It is secured to the main column *b* by collar straps *c* on the lower part, and by the transom extension *d* at the top. The jambs of the door opening are formed of half rounds to correspond to the post *b* and to strengthen the center of the

screen. The space between the post and the partition is fitted with a small bar *f* to fill the space between the column *a* and the side walls. The sill shown in detail at (*f*), Fig. 62,

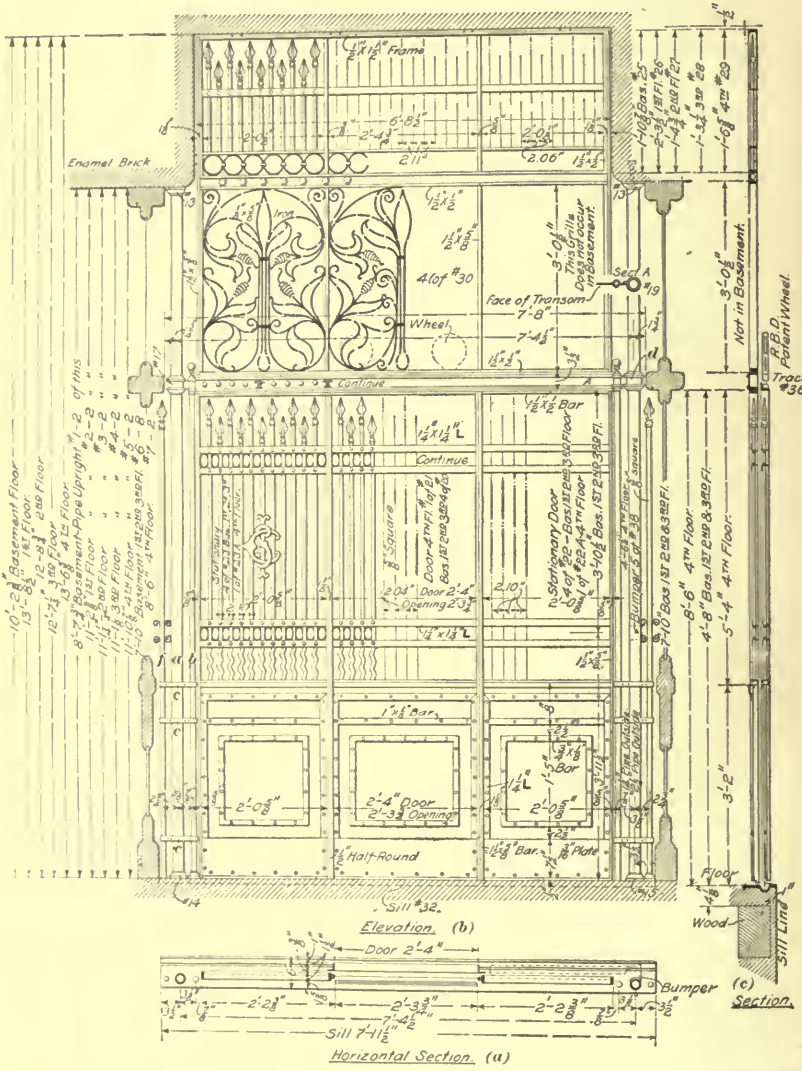


FIG. 61.

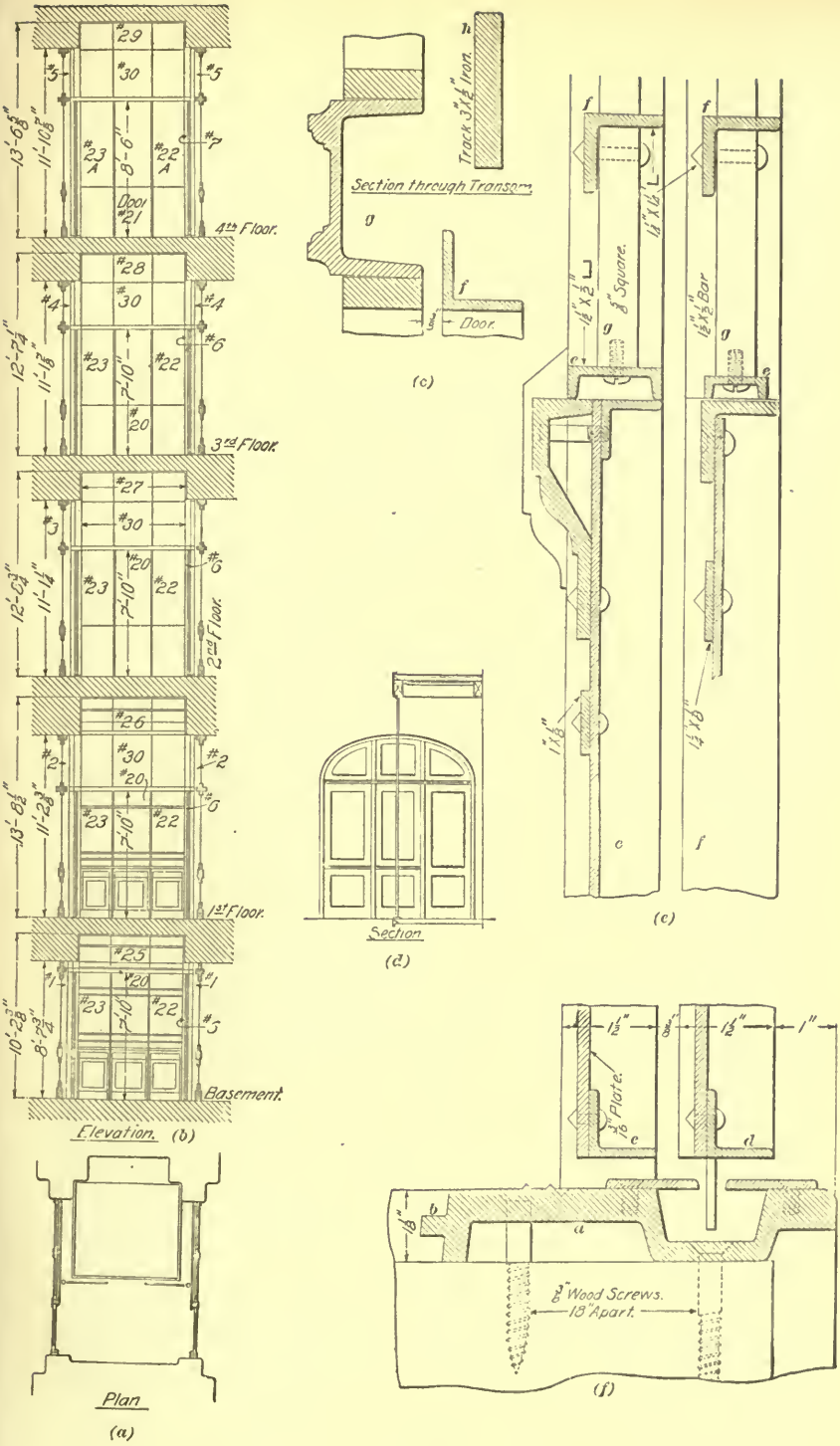

#29
#30
#5
#23 A
8'-6"
#22 A
#7
Door #21
4th Floor.
#28
#4
#6
#22
2'-10"
#20
3rd Floor.
#27
#3
#20
2nd Floor.
#26
#2
#25
#1
Basement.
Elevation. (b)
Plan
(a)
Track 3½" Iron.
Section through Transom.
g
f
Door.
(c)
1½" x ½"
8" Square.
1½" x ½" Bar
1" x ⅛"
1¼" x ⅛"
c
f
(e)
Section
(d)
1½"
⅜"
1"
¼" Plate.
d
b
a
⅜" Wood Screws.
18" Apart.
(f)

FIG. 62.

has a tongue *b* cast on it to receive the finished floor, which is grooved to fit over this tongue and thereby make a snug and unyielding joint. The stationary panels of the screen each side of the door have a dado panel in plate iron, and grille-work above; the same treatment being used in the door.

41. A section of the screen at *c*, Fig. 61, shows the sliding door on the inside of the shaft and the hanger above. Fig. 62 shows, at (*f*), a section through the cast-iron sill and the method of screwing it to the wooden-floor construction. At *d* is a section of the bottom of the sliding door, while at *e* is the fixed panel. The sections of the upper moldings on the dado panel of the door and screen are shown in Fig. 62 (*e*); and at *g* is seen the elevation of the lower part of the bars of the grille, and the screw which secures each of them to the channel iron forming the surrounding and protecting frame. In Fig. 62 (*c*) a section of the transom bar is shown at *g*, a section of the top of the door at *f*, and the track on which it slides at *h*.

42. The general construction of all elevator enclosures is pretty much the same as the examples given in the preceding figures, and further details are unnecessary. In the enclosure screen shown in Fig. 63, the architrave is of cast iron, the general outlines and form of which are designed to correspond with the adjoining trim. This architrave is decorated on the jamb side with a spool-and-spindle fillet mold, and on the outer edge with an egg-and-dart echinus molding. The dado panel is of sheet iron surrounded with a tooth molding, and the center decorated with a wreath of myrtle leaves, berries, and ribbon in wrought or cast iron. The grille of the door is much closer than the transom grille, thus giving a heavier and close effect in the proper place. Both these grilles are formed of $\frac{1}{16}'' \times \frac{3}{8}''$ strap iron set with the edge to the front, the very open portions being relieved by twisting the bars so as to produce a spiral, showing the full width of the bar to the front.

43. In Fig. 64 the whole screen is formed of wrought iron, except the transom bar. This design presents several

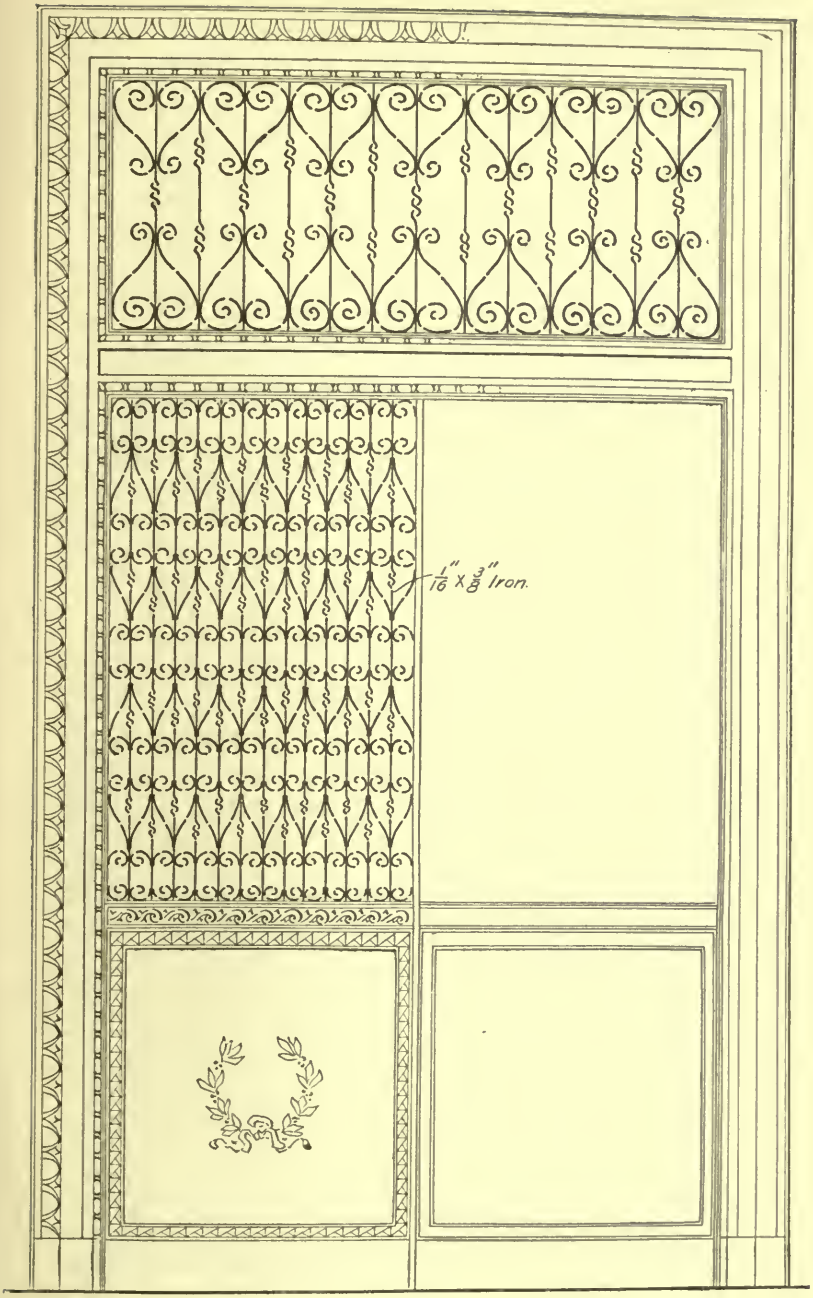


FIG. 63.

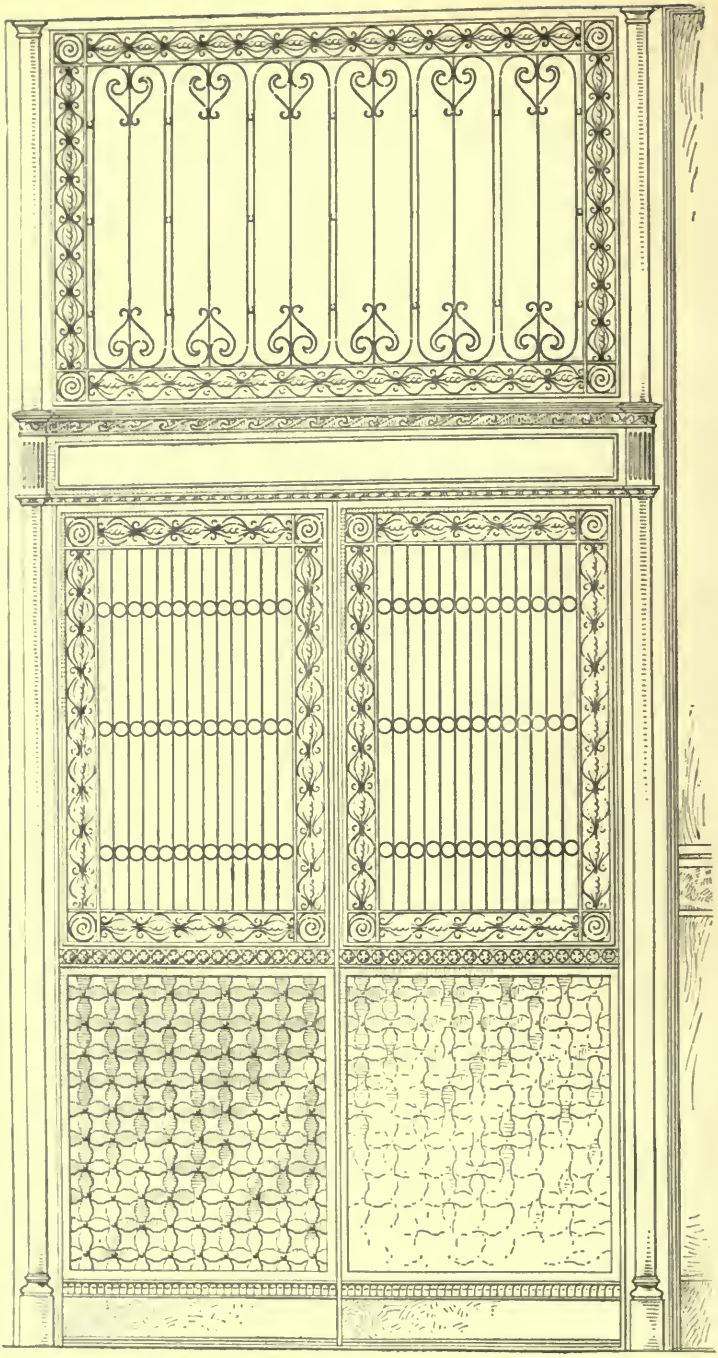


Fig. 64.

most agreeable and pleasing features; it is well balanced, and the transition, which should always be studied in design, from the heavy effect in the dado to the light area in the transom, is here well defined. The dado is especially good, as it combines protection, good design, and cheapness. The pattern, which is a diaper, is made of the usual basket strap work with the edges cut to the form shown. The rail is not too heavy, and shows a molding with a rosette-and-leaf decoration. The filling of the panel is of a series of bars well braced and bound together with three rows of rings. The transom bar—the only piece of cast iron—is finished at the ends with fluted and molded collar bands, through which the columns supporting the screen pass. The transom grille border is a repetition of the door grille, and the center is composed of six very open panels, separated by small button washers, thus completing the screen.

COMBINED ELEVATOR AND STAIR SHAFTS.

44. In fireproof buildings it is a common practice to combine the elevators and stairs in one shaft. In such cases the elevator usually occupies the center of the shaft, and the stairway is constructed around it. Such a combination is shown in plan in Fig. 65, where the arrangement of stairs and elevator shaft on the first floor is shown at (*a*), and on the upper floors at (*b*). An elevator shaft 6 ft. × 6 ft. 9½ in. is thus provided, around three sides of which rises a stairway 3 ft. 2½ in. in the clear. So far as the details of the stairs are concerned, they are precisely the same in principle as those described in Arts. **18, 19,** and **20;** the wall strings are first set in place, then the face strings (which in this case are the *well* strings), and finally the risers and treads. The well strings, however, have to be considered with the elevator shaft, as they form a part of that structure; and the details of the grille-work screen around the elevator shaft must include a treatment that will take the place of a balustrade on that side of the stairs.

The elevations of the wall strings, the outside strings, and

the sides and back of the enclosure, also the front elevation of the enclosure, are shown at (*a*), (*b*), (*c*), and (*d*), in Fig. 66.

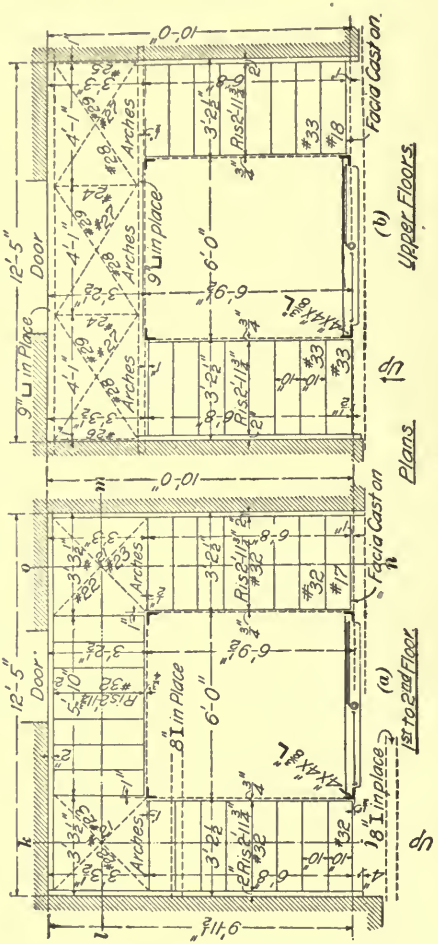


FIG. 65.

The grille-work on the first story is of brass, and on the stories above of iron.

45. As in the previous examples of stair work, the first procedure is to fix the number of risers and the width of the stairs. The height, as shown at (*a*), is 14 ft. $8\frac{1}{4}$ in. between

the first and second stories; and to determine the number of risers, the size of the well hole, as well as the approximate space that the elevator will occupy, must be considered, though the latter may be modified to work out the stairs.

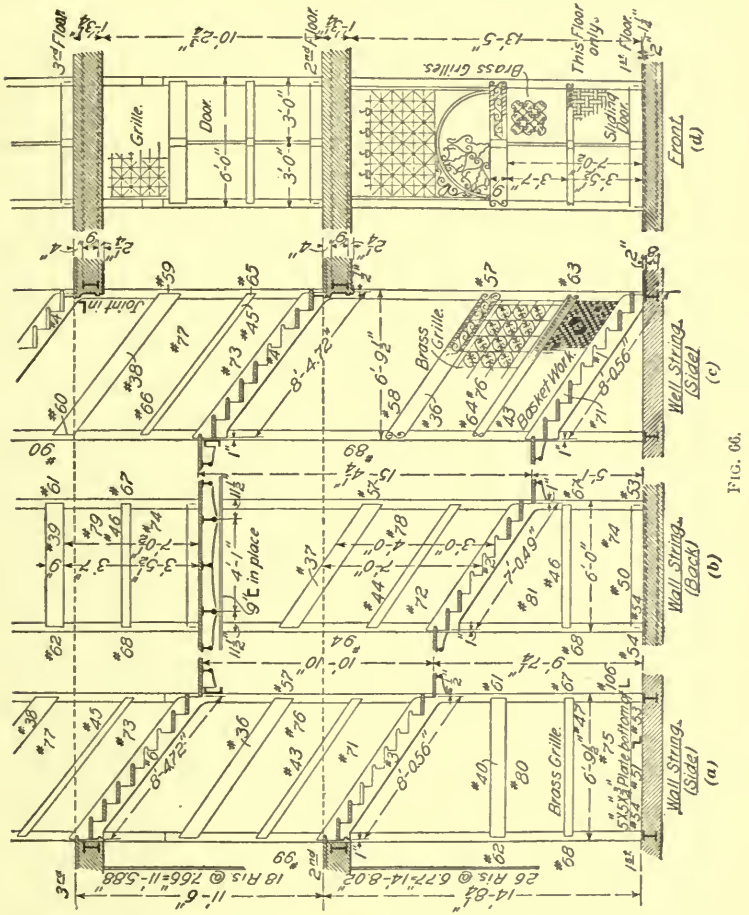


FIG. 66.

It will be seen that 26 risers at 6.77 inches high, counting from the top to top of the treads, gives 9 risers each side of the well and 8 at the back. This will permit the treads to be 10 inches wide on the sides and back, all finishing nearly symmetrically at the corners. The face of the first riser, as

shown in Fig. 65 (*a*), is ½ inch from the corner of the angle-iron frame of the well, and the ninth riser is 1 inch from the corner of the corresponding angle at the back of the shaft.

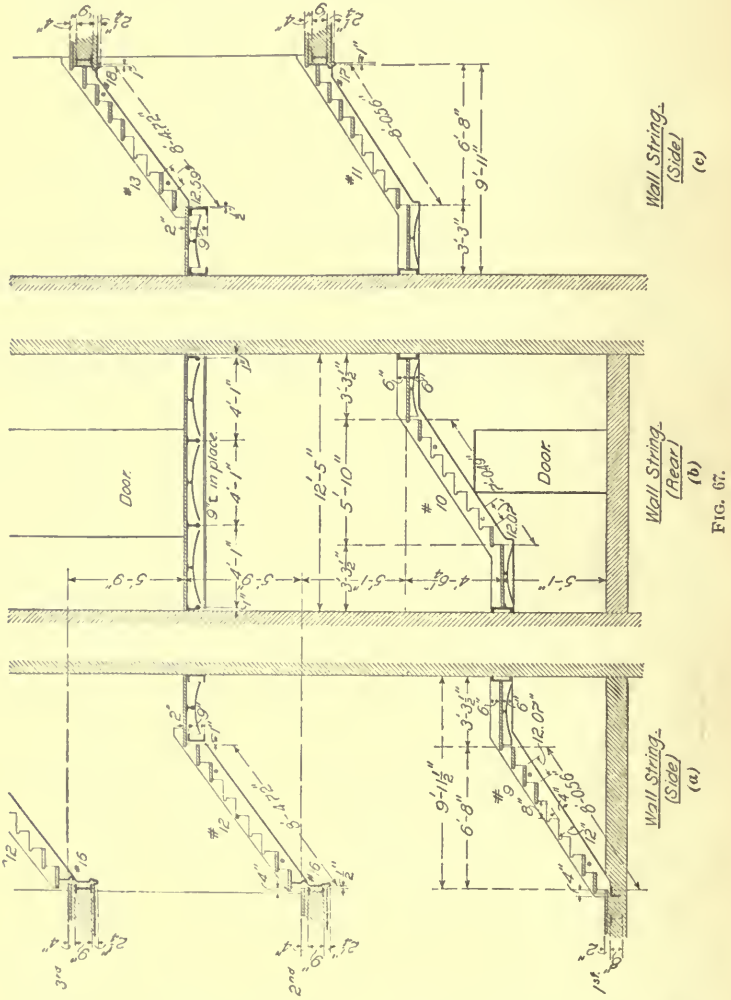
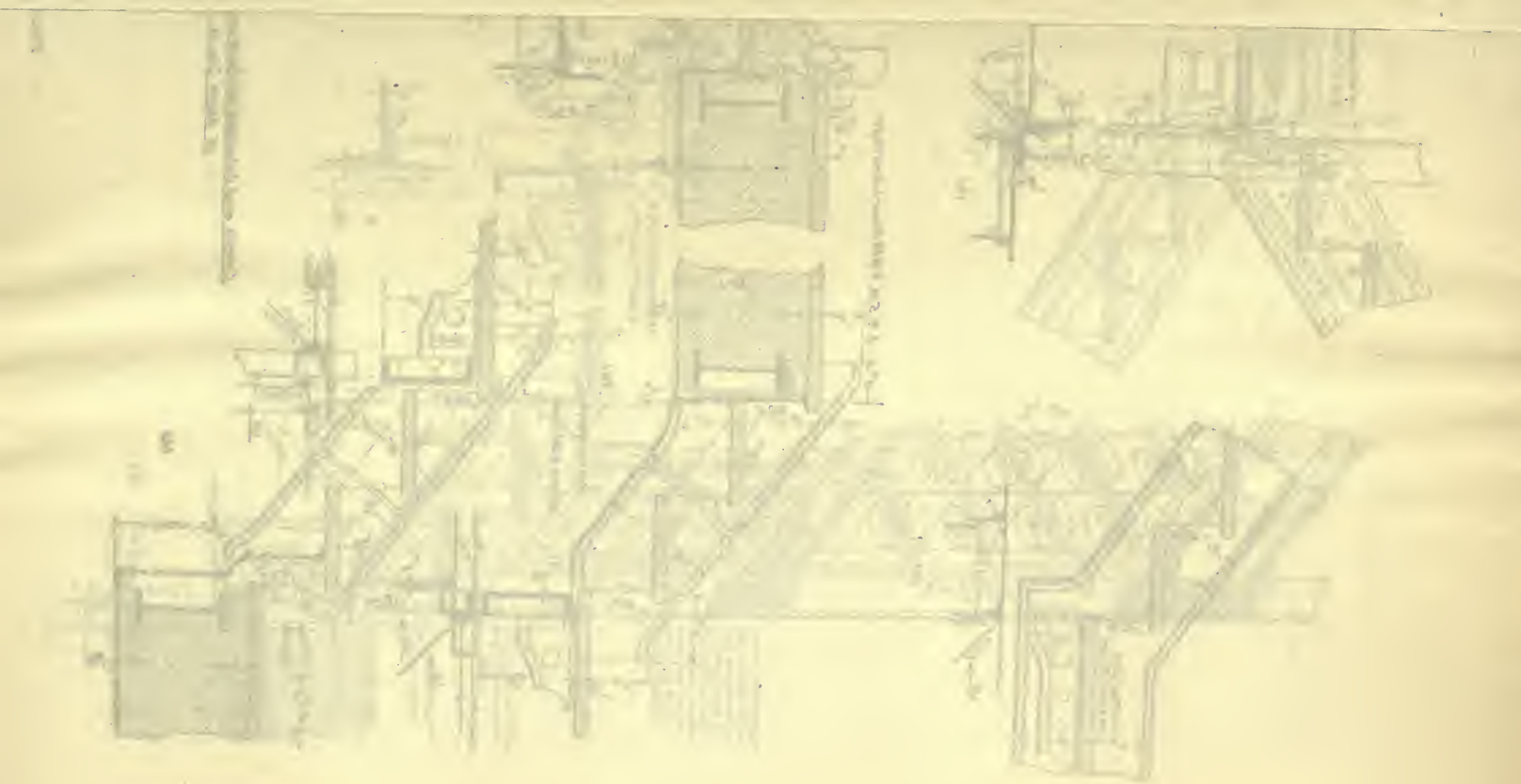
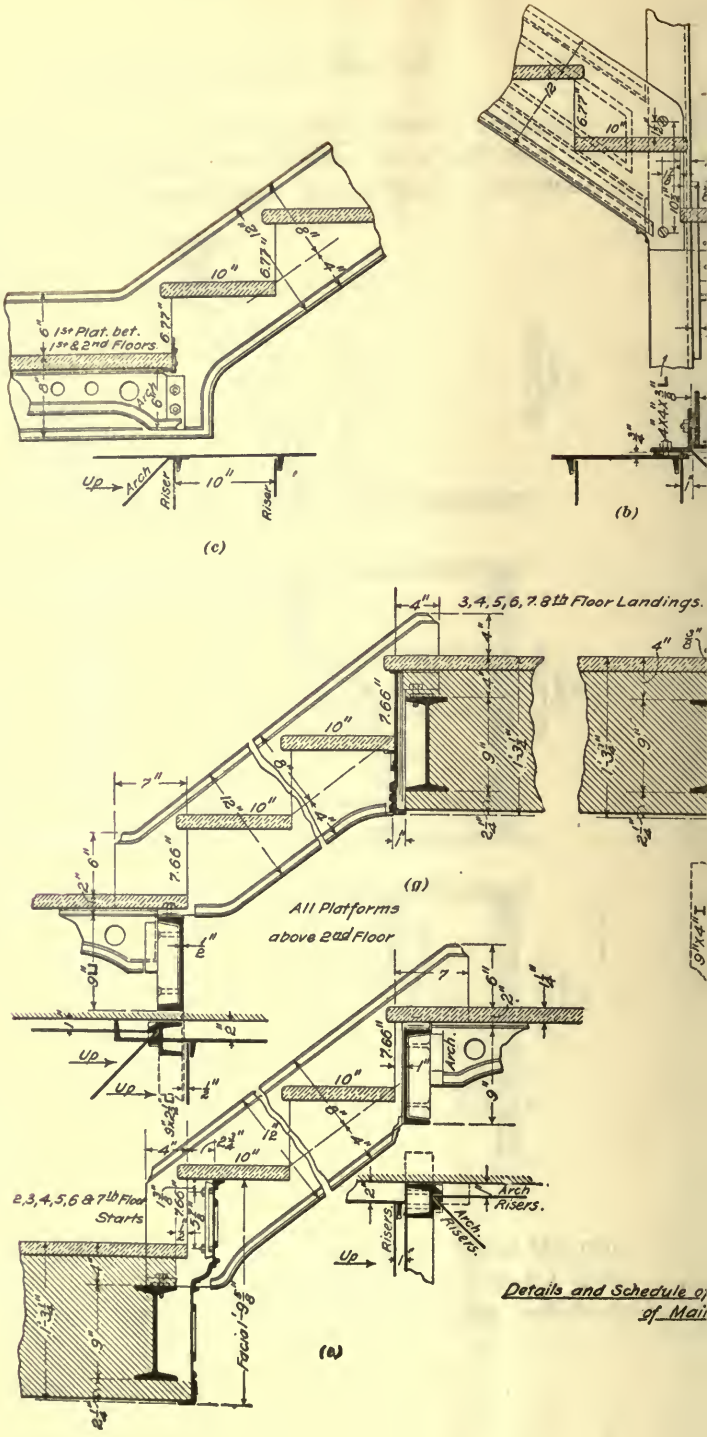
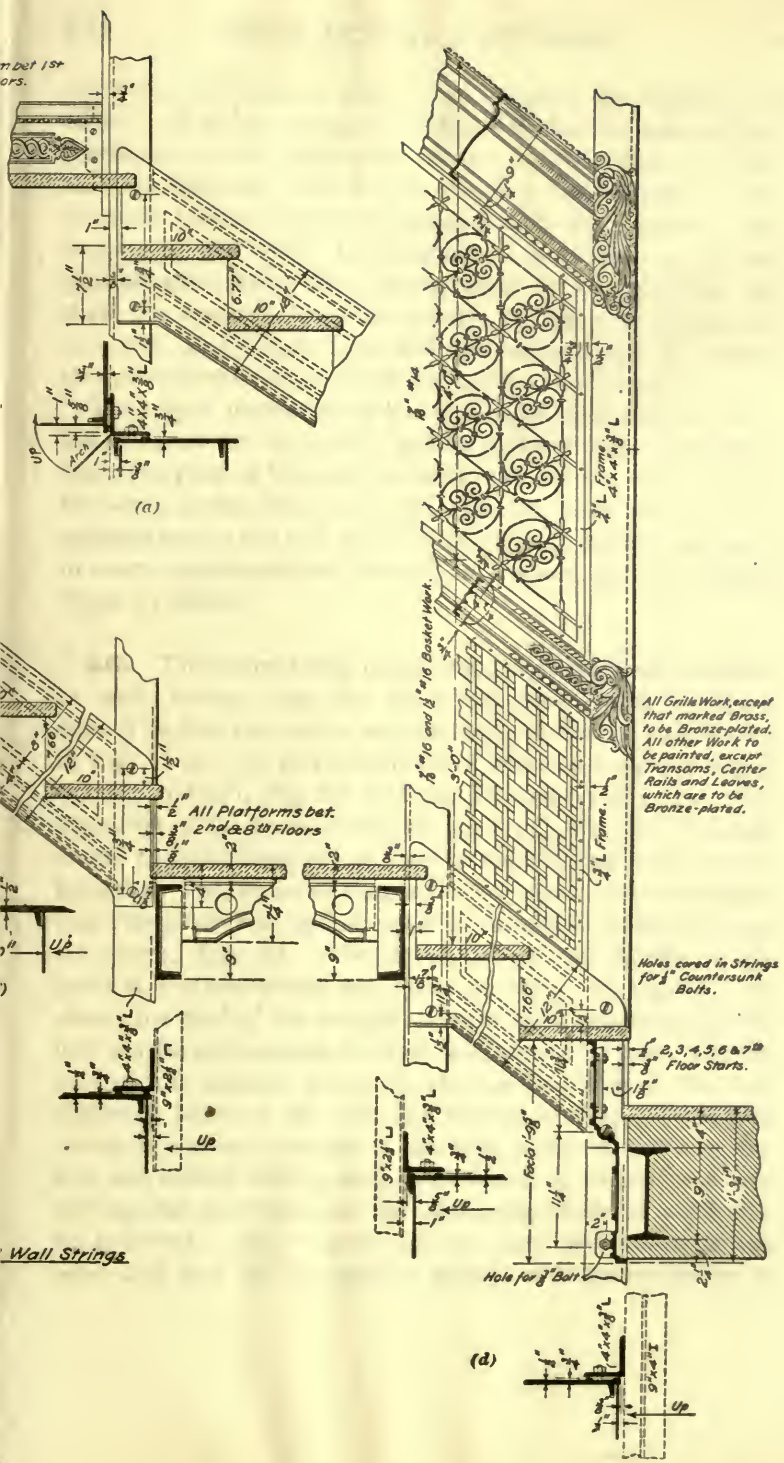


FIG. 67.

The upper part of the opposite side is similar, and the run at the back has the tenth and seventeenth risers, each 1 inch back of the angle iron, thus in each case allowing sufficient




1st Plat. bet. 1st & 2nd Floors
Up
Arch
Riser
10"
Riser
(c)
(b)
3,4,5,6,7,8th Floor Landings.
All Platforms above 2nd Floor
(a)
2,3,4,5,6 & 7th Floor Starts
Arch Risers.
Arch Risers.
Risers.
Details and Schedule of
of Mai


(a)
All Grille Work, except that marked Brass, to be Bronze-plated. All other Work to be painted, except Transoms, Center Rails and Leaves, which are to be Bronze-plated.
Holes cored in Strings for ⅜" Countersunk Bolts.
2, 3, 4, 5, 6 & 7th Floor Starts.
Hole for ⅜" Bolt
(d)
All Platforms bet. 2nd & 8th Floors
Wall Strings

room for the finished tread to stop inside the edge of the angle. In planning any stair that is broken by intermediate platforms, the starting riser of each section should, if possible, be kept the same distance from a fixed point; in this example these points are represented by the angles at the corners of the well. Circumstances may arise, as in the present case, when this arrangement is not possible, and then the space is divided equally, in place of having the eleventh riser $\frac{1}{2}$ inch back, and the seventeenth $1\frac{1}{2}$ inches; this also allows the platform to be the same breadth.

The upper stories being less in height than the first story, fewer risers are required; and by making them 7.66 inches high, the plan of the stair on each side of the well remains the same as the first story, while at the back the platform extends across the full width of the well. In fact, the stairs in every case should be planned as a whole, and not simply flight by flight.

46. The plans being determined, the wall and outside, or well, strings, and the sides and back of the enclosure should be laid out on the section lines *j k*, *l m*, and *n o*, shown in Fig. 65 (*a*), the developments of which are shown at (*a*), (*b*), (*c*), and (*d*), Fig. 66, and (*a*), (*b*), and (*c*), Fig. 67. The elevation of the front is also shown at (*d*), Fig. 66. In most stairs, the platforms are of slate or marble, and must be supported at the center or diagonally by either cast or wrought iron ribs or arches, as indicated by the dotted lines shown on the plans, Fig. 65. The development and details of the parts of the enclosures and stairs are shown in Fig. 68. (*a*) shows the head of the outside string in plan and section at the first platform, between the first and second stories; (*b*), the foot of the outside string in plan and section at the first platform, between the first and second stories; (*c*), the wall string in plan and section at the first platform between the first and second stories, and an elevation of the arch rib supporting the platform and the springing block to which the rib is bolted. At (*d*) is shown the plan and section of the head and foot of the outside string, with the enclosure of

basketwork and grille as they exist in the upper stories, and (*e*) shows the plan and section of the *wall* string of the same run. At (*f*) is shown a plan and section of the head and

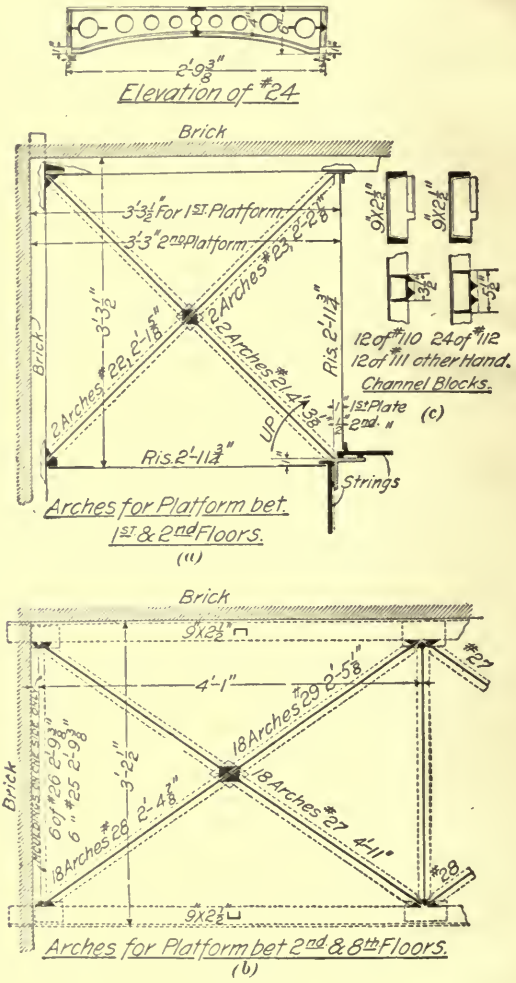


FIG. 69.

foot of the outside string on all the platforms and landings of the upper stories. At (*g*) is shown the wall string and

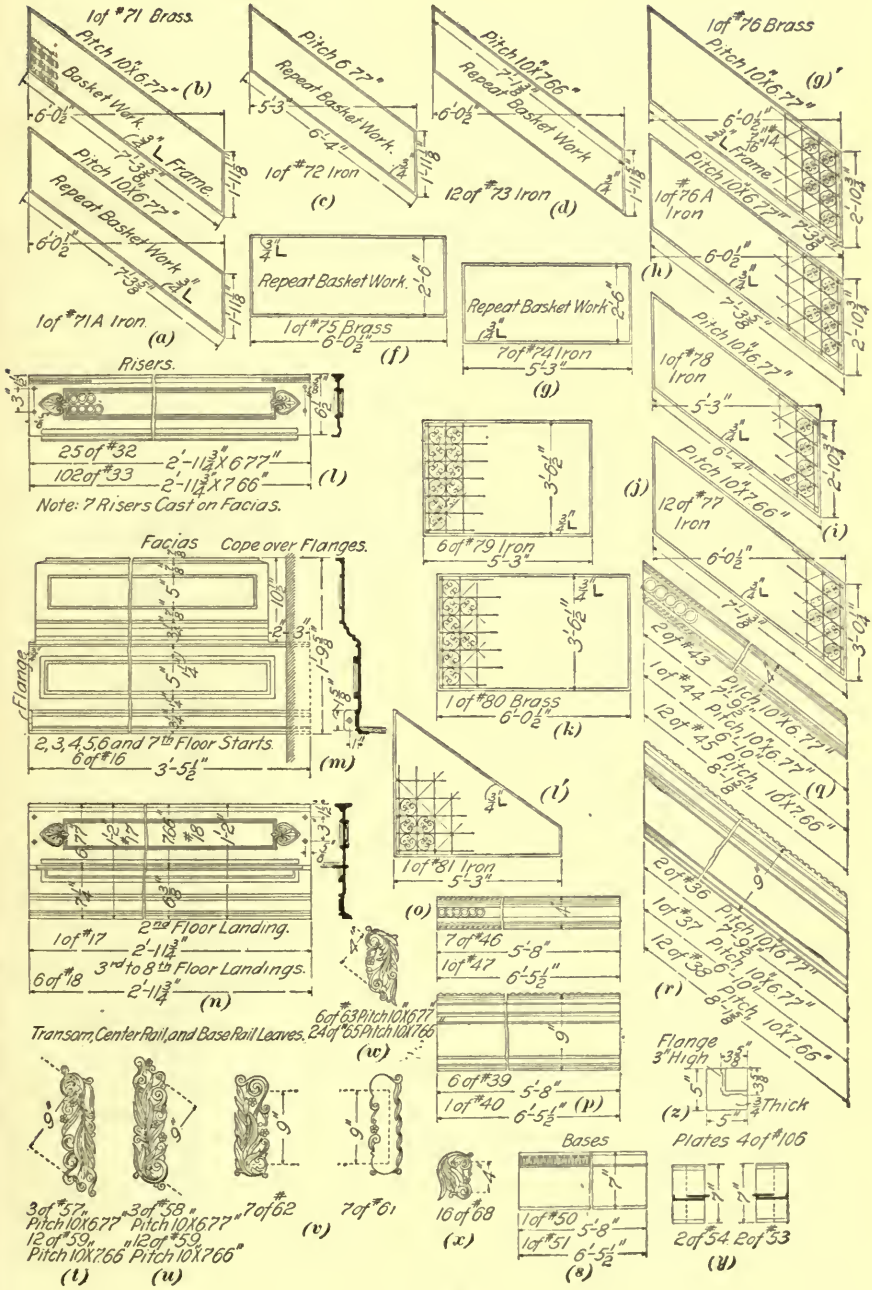

1 of #71 Brass
Pitch 10"x6 77"
Basket Work
6'-0½"
1¼" L Frame.
7'-3⅜"
1-1⅛"
(b)
Pitch 10"x6 77"
Repeat Basket Work
6'-0½"
7'-3⅜"
1¼" L
1-1⅛"
1 of #71A Iron.
(a)
Pitch 6 77"
Repeat Basket Work.
5'-3"
6'-4"
1¼"
1-1⅛"
1 of #72 Iron
(c)
Pitch 10"x7 66"
7'-3⅜"
Repeat Basket Work
6'-0½"
¾" L
1-1⅛"
12 of #73 Iron
(d)
¾" L
Repeat Basket Work.
2'-6"
1 of #75 Brass
6'-0½"
(f)
Repeat Basket Work
¾" L
2'-6"
7 of #74 Iron
5'-3"
(g)
1 of #76 Brass
Pitch 10"x6 77"
(g')
6'-0½"
¾" L
#14
Frame
2'-10¾"
#76A Iron
Pitch 10"x6 77"
7'-3⅜"
(h)
6'-0½"
¾" L
7'-3⅜"
2'-10¾"
1 of #78 Iron
Pitch 10"x6 77"
5'-3"
¾" L
6'-4"
2'-10¾"
(i)
12 of #77 Iron
Pitch 10"x7 66"
6'-0½"
¾" L
7'-1⅛"
3'-0¼"
(j)
Risers.
3¾"
6½"
25 of #32
2'-11¾"x6 77"
102 of #33
2'-11¾"x7 66"
(l)
Note: 7 Risers Cast on Facias.
3'-0½"
¾" L
6 of #79 Iron
5'-3"
3'-0½"
¾" L
1 of #80 Brass
6'-0½"
(k)
Facias
Cope over Flanges.
Flange
10"
2"
3"
1-9⅜"
2, 3, 4, 5, 6 and 7th Floor Starts.
6 of #16
3'-5½"
(m)
2 of #43
1 of #44
12 of #45
Pitch 10"x6 77"
Pitch 10"x7 66"
(q)
¾" L
1 of #81 Iron
5'-3"
(l')
6 of #17
12"
7 of #18
12"
3"
2nd Floor Landing.
1 of #17
2'-11¾"
3rd to 8th Floor Landings.
6 of #18
2'-11¾"
(n)
7 of #46
5'-8"
1 of #47
6'-5½"
(o)
2 of #36
1 of #37
12 of #38
Pitch 10"x6 77"
Pitch 10"x7 66"
(r)
6 of #63 Pitch 10"x6 77"
24 of #65 Pitch 10"x7 66"
Transom, Center Rail, and Base Rail Leaves.
(w)
6 of #39
5'-8"
1 of #40
6'-5½"
(p)
Flange
3" High
⅜"
5"
5"
¾" Thick
(z)
Plates 4 of #106
9"
3 of #57, Pitch 10"x6 77"
12 of #59, Pitch 10"x7 66"
(t)
9"
3 of #58, Pitch 10"x6 77"
12 of #59, Pitch 10"x7 66"
(u)
9"
7 of #62
(v)
9"
7 of #61
16 of #68
(x)
Bases
1 of #50
5'-8"
1 of #51
6'-5½"
(s)
7"
7"
2 of #54
2 of #53
(y)

FIG. 70.

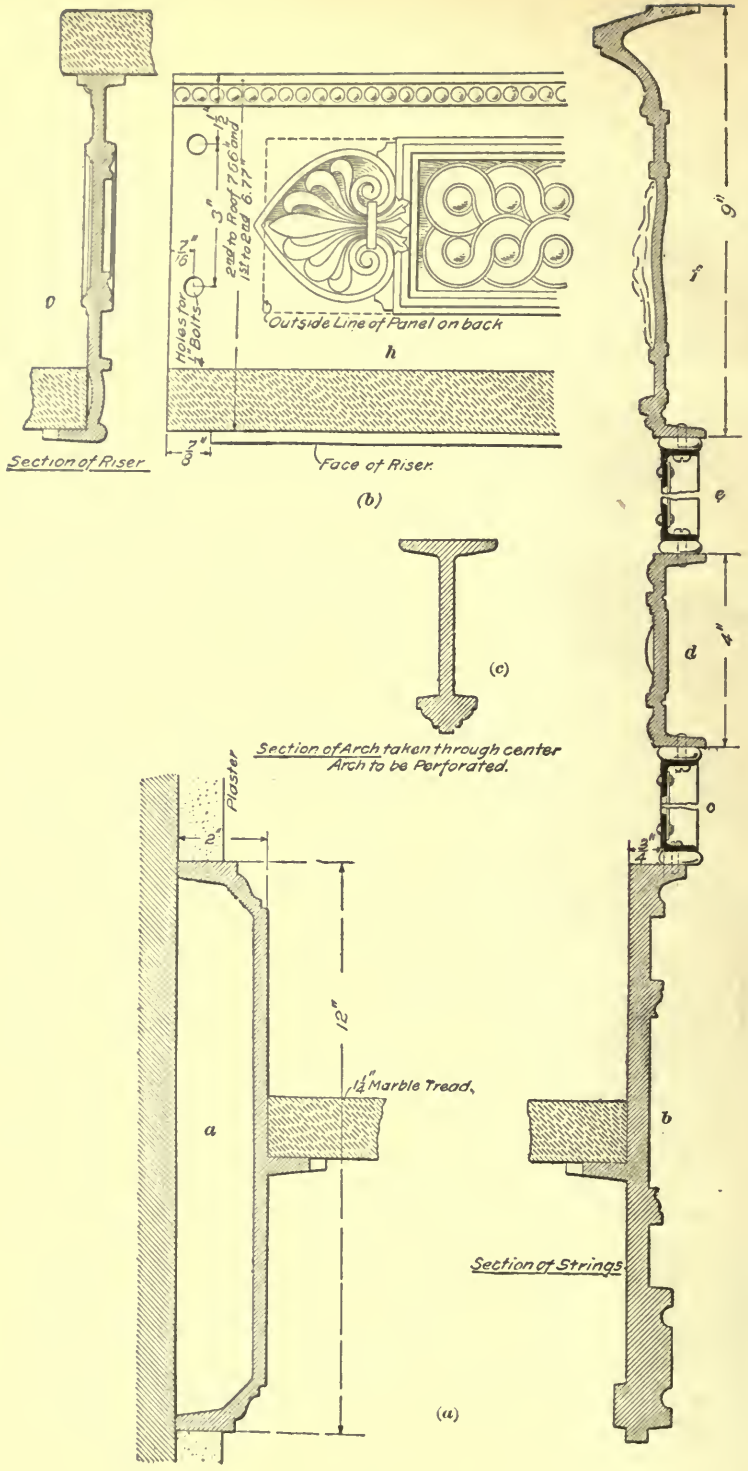

Section of Riser
Holes for ¼ Bolts
3"
2 apt to Roof 7.06 and 1st to 2nd 6.77
1½
Outside Line of Panel on back
h
Face of Riser.
(b)
(c)
Section of Arch taken through center
Arch to be Perforated.
Plaster
2"
12"
1¼" Marble Tread.
a
(a)
9"
f
g
d
4"
o
b
Section of Strings

FIG. 71.

the platforms and landings of the same run. In Fig. 69 is shown the elevation and section of the rib arches that support the platforms. The ends are checked out $\frac{3}{4}$ in. $\times 1$ in. where they rest on the springing blocks as shown. Fig. 69 shows at (*a*) the plan of these platform arches for the first story, and at (*b*) for the upper stories, while the springing blocks that support these ribs are shown at (*c*). They are cast channel shape, with the web, or socket, and the lug on the face.

47. The risers shown in Fig. 70 (*l*) are for all starters on each floor, and for all intermediate risers. The facias shown in Fig. 70 (*m*) are at the start of the upper stories, and form a finish from the first tread to the plaster of the ceiling below. The seven risers cast on the facias are shown at (*n*), and are for the upper landings, and form a finish from the last tread to the under side of the plaster. The top rails, center rails, and bases are shown at (*o*), (*p*), (*q*), (*r*), and (*s*); the base (*s*) finishes the enclosure on the first floor only. The center rails (*o*) and (*p*) extend throughout all floors, as do the top rails (*q*) and (*r*). The leaves forming the finish, and covering the joints of the transom, center rail, and base rail, are shown at (*t*). The finish at the base of the angle irons at the first floor is shown at (*y*) and (*z*), the latter being the plate which is bolted to the I beams to form the foundation of the enclosure, the four angles at the corner being bolted to these plates. The basket grille which forms the dado of the enclosure is shown at (*a*), (*b*), (*c*), (*d*), (*f*), and (*g*), and the grille-work at (*g'*), (*h*), (*i*), (*j*), (*k*), and (*l'*).

48. Fig. 71 (*a*) shows the strings, enclosure, arch, and riser in detail. The wall string is shown at *a*, and the well string at *b*; the frame of the basket grille composed of small angle irons is shown at *c*, and the center rail at *d*; the grille frame composed of small angles at *e*, and the top rail at *f*. A section of the riser and an elevation of the front of the same are shown at *g* and *h* in Fig. 71 (*b*), and the arch rib at (*c*).

ELEVATOR CARS.

49. Elevator cars are usually constructed of angle-iron or pipe framework, and filled in with woven-basket and twisted-iron grille-work and scrollwork. The design of the grille-work is usually similar to, if not identical with, the design of the grille of the enclosure, though sometimes certain conditions require a stronger and less elaborate design in one place than in the other.

In Fig. 72 is shown a plan at (*a*), and a section or interior elevation at (*b*), of an elevator car, the design of which is simple and inexpensive, while the construction is substantial and serviceable.

The plan (*a*) shows two recesses at *a*, in which are located the guides, thus permitting the car to extend the full width of the shaft. The frame of the car is composed mostly of wrought-iron pipe, as shown at *b* in the plan, between the vertical members of which small channels *c* are secured to receive the basketwork and grilles. On the inside of the car the guides are covered with sheet-iron dado panels, extending 2 ft. 9 in. above the floor and with a beveled plate-glass mirror from here to the top of the car. The rest of the side walls of the car, with the exception of the door, is composed entirely of grille-work.

50. The dado consists of a simple basketwork of $1\frac{1}{2}$-inch iron straps, spaced $\frac{3}{4}$ inch apart and secured by riveting the end of each strap to the leg of a 1-inch angle iron, as shown at *f*. The space between the dado and the grille-work consists of a sheet-iron panel secured in place by riveting it to the vertical legs of two 1-inch angle irons, which are framed in between the vertical supports.

The grilles forming the upper part of the elevator are composed of $\frac{1}{2}'' \times \frac{3}{16}''$ bars *d*, which are held vertically in place by means of $1'' \times \frac{1}{4}''$ horizontal rails *e*, through which the vertical members extend. By arranging the rails in pairs, and keeping their distance apart equal to the spaces between the vertical members, a series of squares is formed, in which rings are inserted, as shown at *g*, thus bracing the joint and

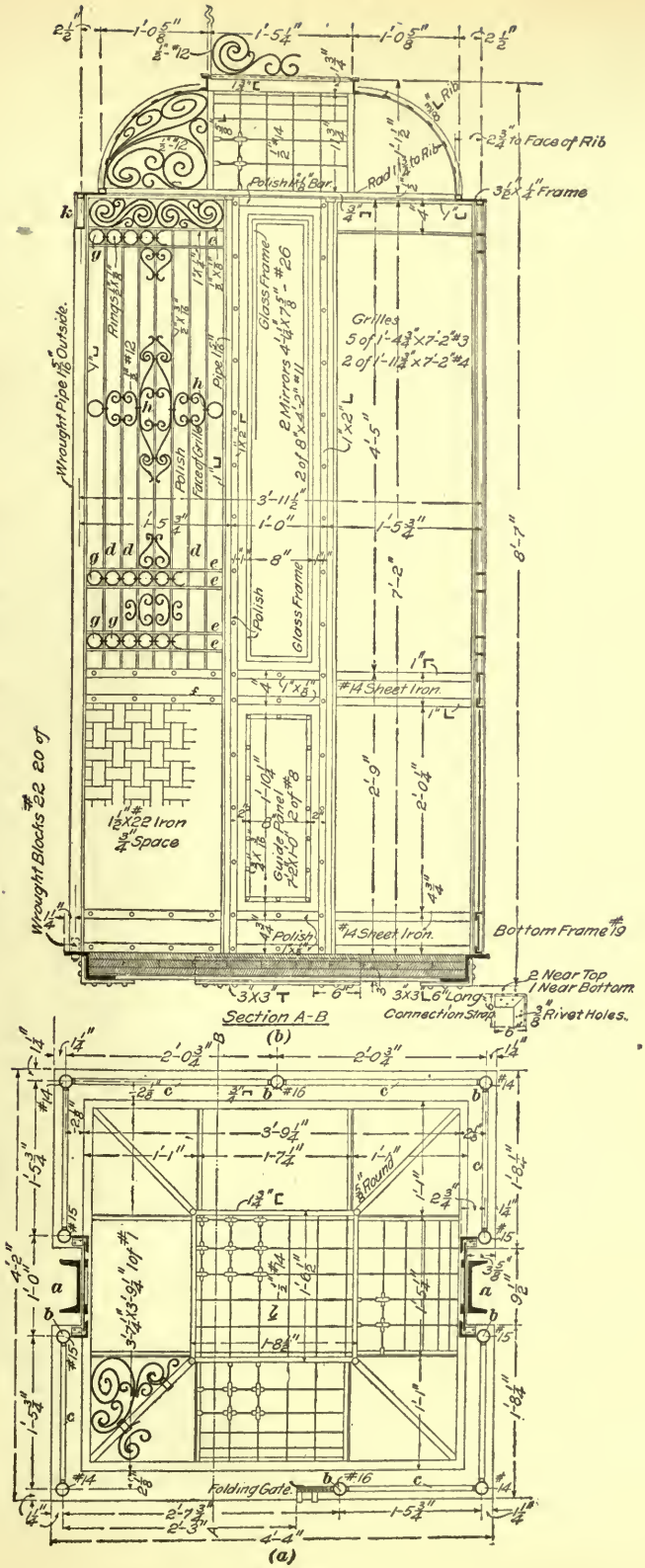

Wrought Pipe 1½" Outside.
Wrought Blocks #22 20 of
1½"x2 Iron
¾" Space
Grilles
5 of 1'-4¾"x7'-2" #3
2 of 1'-11¾"x7'-2" #4
2 Mirrors 4'-4"x7'-5⅞" - #26
2 of 8"x4'-2" #11
Glass Frame
Polish
Face of Grille
Pipe 1½"
Amps 1¼"
Rod 1¼" to Rib
2¾" to Face of Rib
3½"x¼" Frame
L Rib
#14 Sheet Iron
Guide Panel 2 of #8
Bottom Frame #19
2 Near Top
1 Near Bottom
¾" Rivet Holes.
3x3 6" Long Connection Strap
Section A-B
(b)
(a)
Folding Gate.
1½" Round
#16
#14
#15
#12
#8
#4

FIG. 72.

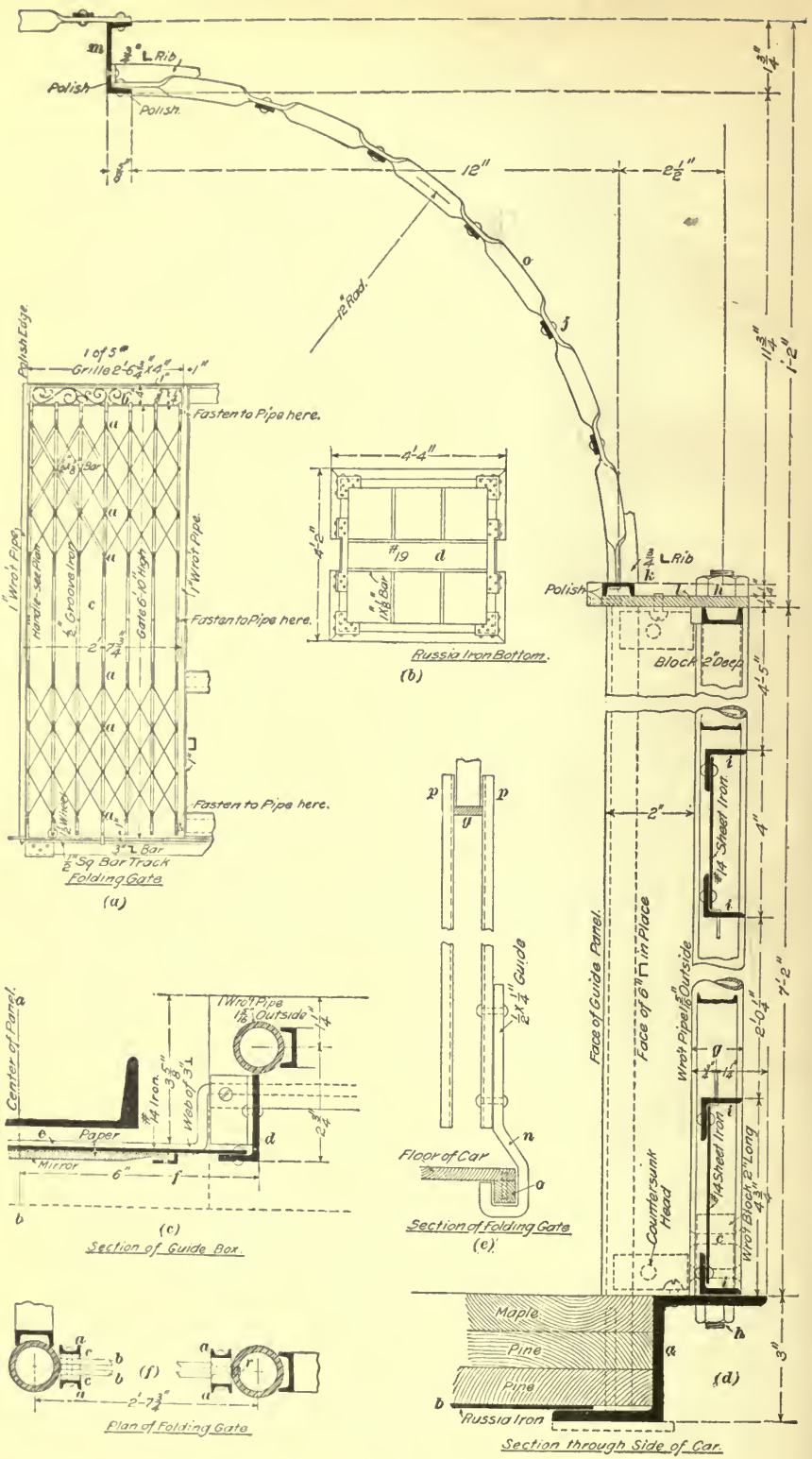

Polish
Polish
12" Rod
12"
2½"
Polish Edge
Fasten to Pipe here.
Fasten to Pipe here.
Fasten to Pipe here.
Gate 6'-0" High
Folding Gate
(a)
4'-4"
4'-2"
Russia Iron Bottom.
(b)
Polish
Block 2" Deep
Face of Guide Panel.
Face of 6" ⊓ in Place
Wrot Pipe 1½" Outside
Sheet Iron
Counter sunk Head
Wrot Block 2" Long
Maple
Pine
Pine
Russia Iron
Section through Side of Car.
(d)
Floor of Car
Section of Folding Gate
(e)
Center of Panel.
Wrot Pipe 1½" Outside
Web of 3"⊥
Paper
Mirror
6"
Section of Guide Box.
(c)
2'-7¾"
Plan of Folding Gate
(f)

FIG. 73.

rendering the entire grille stiff and secure. Across the middle of the grille, a series of scroll ornaments relieves the plainness of the panel, while at the same time it gives lateral stiffness to the vertical bars. At the top of the wall panels a scroll design forms a frieze at the ceiling line, and serves to combine the character of the side walls with that of the domed roof. The grilles of the roof are composed of simple twisted strap iron, such as was described in Art. **33**, on the sides, and of a more elaborate scrollwork in the angles.

51. In Fig. 73 (*d*) is shown a section through the side of the car, illustrating on a larger scale the details of its construction. The rectangular floor frame is composed of 3-inch **Z** bars, as shown at *a*, and three thicknesses of wood flooring, lined with a Russia-iron shield *b*, rest on the lower flange of the **Z** bar, while the walls of the car are secured to its upper flange. The corner and intermediate supports *g*, composed of $1\frac{5}{16}$-inch wrought-iron pipe, are secured to the upper flange of the **Z** bar *a* at the floor level, and to a $\frac{1}{4}$-inch wrought-iron plate *l* at the top. This is accomplished by plugging the ends of the pipes with wrought-iron blocks and riveting the blocks in place through the pipe, as shown dotted at *c*. The ends of the plugging blocks are then cut with a screw thread and the nuts *h* turned up on them, after their insertion through the flange and plate. Two 1-inch angle irons *i* form the upper and lower members of the frame for the base and middle rail, as shown, and a 1-inch channel, extending full length of the sides and across the top of each panel, secures the grilles and scrolls in their places. A smaller channel *k* rests on top of the plate *l* and receives the lower ends of the vertical members of the roof grille *o*. At *m* another channel set vertically receives the upper ends of the vertical members of the roof grille, and also the ends of the straps forming the center ceiling panel shown at *l* in Fig. 72. The straps of the dome and ceiling grilles are $\frac{1}{2}'' \times \frac{3}{16}''$ iron twisted as shown, and riveted where they cross at *j*, as described in Art. **33**.

52. In Fig. 73 (*c*) is shown a section through the panel and guide at the side of the car, the line *a b* being the center line through the guides. The angle irons *d* are secured to

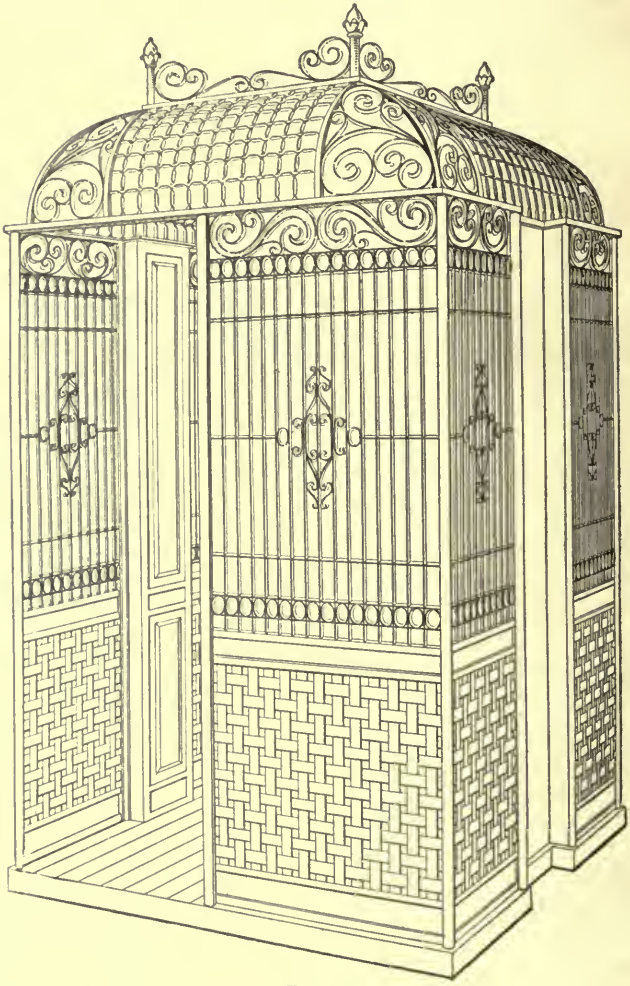


FIG. 74.

the flange of the Z bar at the bottom and to the $\frac{1}{4}$-inch plate at the top by means of small angle-iron knees, and a plate of sheet iron *e* riveted to the short legs of the angles forms the

back of the chase or guide recess. On the inside of the car the mirror is secured against this plate by means of $\frac{5}{8}'' \times \frac{1}{4}''$ angle irons screwed to the chase back with countersunk screw bolts.

53. An elevation of the sliding or rolding gate, protecting the entrance to the car, is shown in Fig. 73 (*a*), while Fig. 73 (*e*) shows a large scale detail of the bottom of the sliding post of the gate *n* and the guide *o* in which it slides. The vertical members of the gate are each composed of a pair of $\frac{1}{2}$-inch channels, as shown at *a* in Fig. 73 (*f*), which is an enlarged plan. Between these channels the diagonal lattice bars *b* are secured as shown, with washers *c* between them to prevent their rubbing together as the gate is opened and shut. The rivets securing this latticework to the channels are not driven tight, but are left sufficiently free to play up and down in the slotted openings shown in the elevation, Fig. 73 (*a*), at *a*. Thus, the gate, which effectively bars the 2 ft. $7\frac{3}{4}$ in. opening in the car, occupies, when open to its fullest extent, only the width of the seven vertical channels, or $3\frac{1}{2}$ inches. On the exterior channel a $\frac{1}{2}'' \times \frac{1}{4}''$ guide is riveted, as shown at *n* in Fig. 73 (*e*), and on the under side of the **Z**-bar flange a track *o* is secured for the guide to travel in. At the top of the gate the $\frac{1}{2}$-inch channels are carried up each side of the frieze grille of the car, as shown at *b* in Fig. 73 (*a*), and also in Fig. 73 (*e*), where the lower bar of the frieze grille is shown at *g* and the side bars or channels at *p*. The general appearance of the car when completed and all of its parts assembled, is shown in Fig. 74.

54. In Fig. 75 is shown a reproduction of a shop drawing of one of these cars, which was to be one of several all constructed alike, and accounts for the excess of material stated on the drawing for the different parts. This car is designed for a similar disposition of tracks and guides as the last example, but the design is more elaborate. The bottom of the car shown at *a* in the interior elevation (*a*) is of wood; the upright framing is of square tubes, as shown in

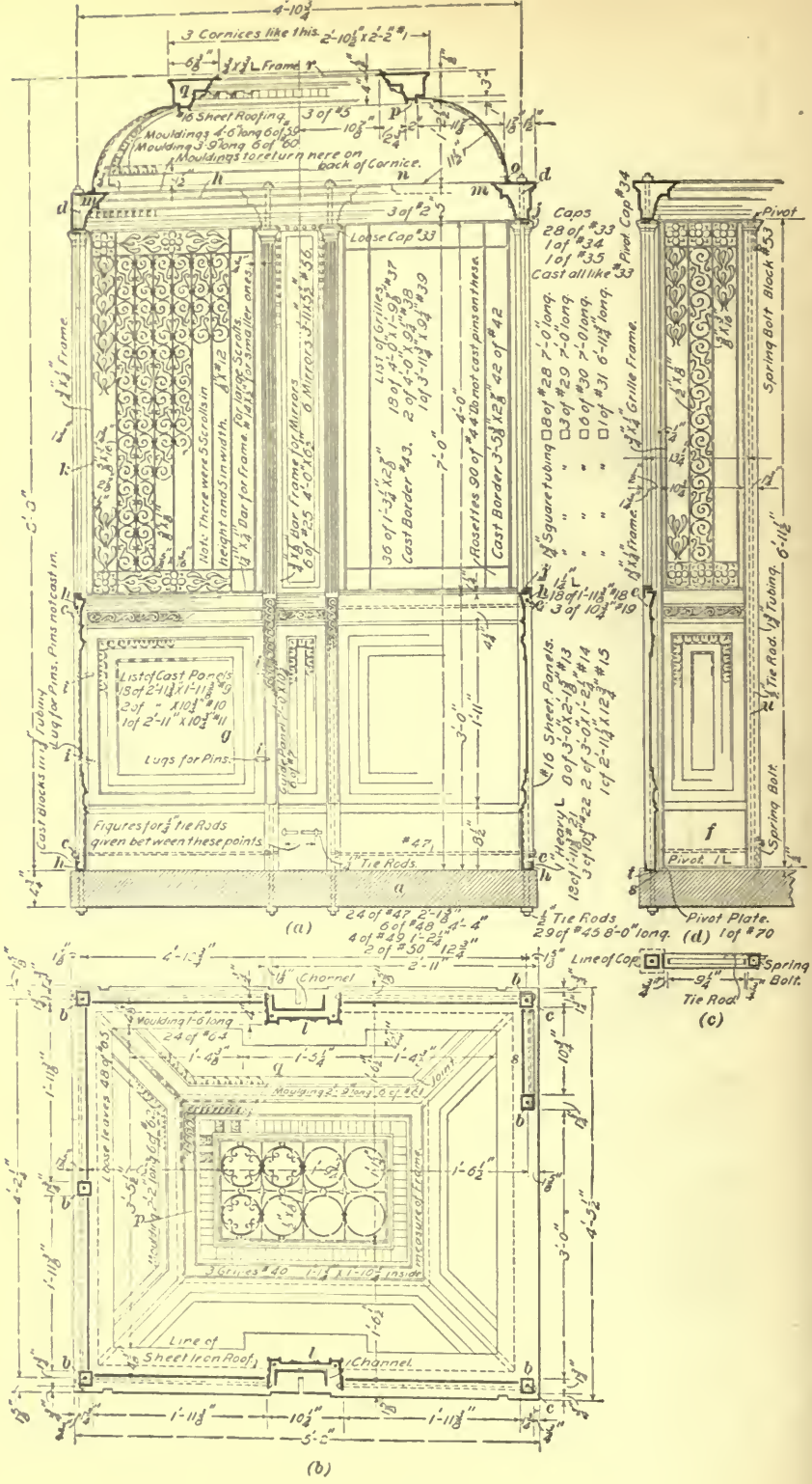

3 Cornices like this.
16 Sheet Roofing.
Mouldings 4'-6" long 6 of #59
Mouldings 3'-9" long 6 of #60
Mouldings to return here on back of Cornice.
Loose Cap #33
Caps
28 of #33
1 of #34
1 of #35
Cast all like #33
Pivot
Pivot Cap #34
Spring Bolt Block #53
Grille Frame.
Tubing.
Tie Rod.
Spring Bolt.
Pivot Plate.
Cast Blocks in ends of Tubing
Lugs for Pins. Pins not cast in.
Lugs for Pins.
Figures for ¾" Tie Rods given between these points.
Tie Rods.
16 Sheet Panels.
Line of Cap.
Channel
Line of Sheet Iron Roof.
Tie Rod
(a)
(b)
(c)
(d)

FIG. 75.

the plan at *b*, inside of which an iron rod *c* passes through the floor and the cornice *d*, and secures these parts as shown. The framework is bound together horizontally by rods at the rail and base, as shown in the elevation at *e*, and by the cornice at the top. Similar rods are placed in the corners behind the projecting panels on each side, thus binding the whole car together. The top of the car is of sheet iron, and, being dome-shaped, is self-supporting. The sides of the car are of cast iron *below* the rail, and cast and wrought iron above, with a mirror on each side. The small section of front shown in the plan at *s* is made to swing inwards, to allow the use of the full width of the car in taking on merchandise. The outside of the car below the rail is covered with sheet iron. The dado of the side shown at *g* in the elevation (*a*) is cast in one piece, including the base, panel, frieze, and cap. The base and cap are plain molded; the outside molding of the panel is decorated with a link leaf and the inner with a spool-and-reed ornament. The casting is secured at the top and bottom by bolts through the angle irons *h*, which are framed in between, and bolted to, each pair of corner posts. At the sides the panels are held by small lugs cast on them to receive dowel-pins, as shown at *i*. The top and bottom of the outside frames for the grilles shown at *j* are made of bar iron $1\frac{1}{4}$ in. $\times 1\frac{1}{4}$ in., and the sides *k* of $\frac{3}{4}'' \times \frac{1}{4}''$ iron. The inside frame dividing the cast-iron border and the grille is of $\frac{5}{8}$ in. $\times \frac{3}{16}$ in., as shown; the bars of the grille are $\frac{5}{8}$ in. $\times \frac{1}{8}$ in., and the scrolls are all $\frac{1}{8}$ inch thick. The cast-iron border of the grille is a laurel-leaf design with a rosette in each corner and in the center of the top and bottom sections. The scrolls are secured to the frame by rivets, but to the bars they are held by straps. The cast-iron guide box, shown at *l* in the plan, is strengthened at the corners and finished on the inside with a pilaster, the upper part or shaft of which is fluted and finished with a cap, while the pedestal is paneled and filled with a guilloche ornament. The cornice is of cast-iron, molded and ornamented with a dentil course, as shown on the interior elevation, while on

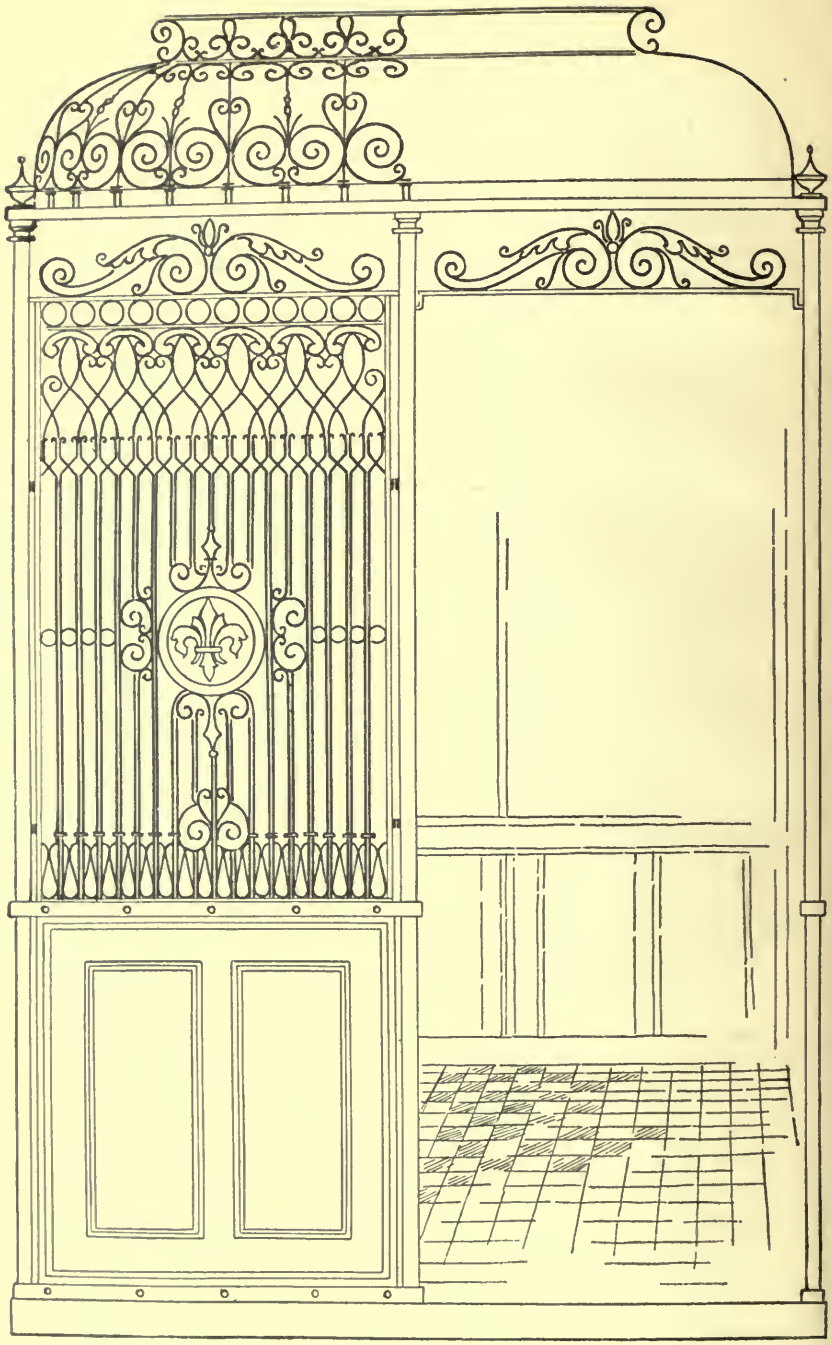


Fig. 76.

the back it is finished with small moldings top and bottom, which return as indicated by the dotted lines *n*. The dome plates are mitered at the angles and paneled on the inside face. The miters are covered by bronze spool-and-reed moldings, and the panel molding is decorated with a leaf link. The dome plates are secured to the vertical leg of an angle *o*, which is riveted to the top of the cornice of the car; and the cast-iron cornice of the *dome* is supported by these dome plates. The soffit of this dome cornice is decorated with a guilloche and flower rosette, as shown at *p* in the plan; while its facia and corona are supported on modillion brackets, as shown at *q*. The dome grille *r* is designed suggestive of the usual treatment of a ceiling, being first divided in panels, which are afterwards filled with a circle, and the circle with a quarterfoil of scrolls. This grille is set in an angle-iron frame, which is bolted to the cornice. The swinging door shown in the plan at *s* is seen in elevation at (*d*). The pivots *s* are riveted to the frame of the grille, the top one being inserted in the cornice and the bottom one in the pivot plate *t*. The top and bottom of the post *u* are fitted with spring bolts, which are withdrawn when the section is to be opened. By a careful inspection of the details of the preceding examples, the construction of elevator cars should now be fully comprehended; and, as such work does not differ materially, the student should be able to design the construction details of any car required.

55. In Fig. 76 is shown a design for an elevator car entirely of wrought iron. The grille differs from the previous examples, as it has no border, but is divided into a dado, field, and frieze. The dado is composed of an interlaced leaf; the field has a cartouche with a fleur de lis in the center, and the frieze with an interwoven pattern ending in scrolls. The panels which take the place of the cornice are filled with scrolls, and decorated with leaves having a flower or bud at the center. The grille of the dome is in motive similar to the honeysuckle-link decoration used in classic architecture. The car illustrated at Fig. 77 is wrought

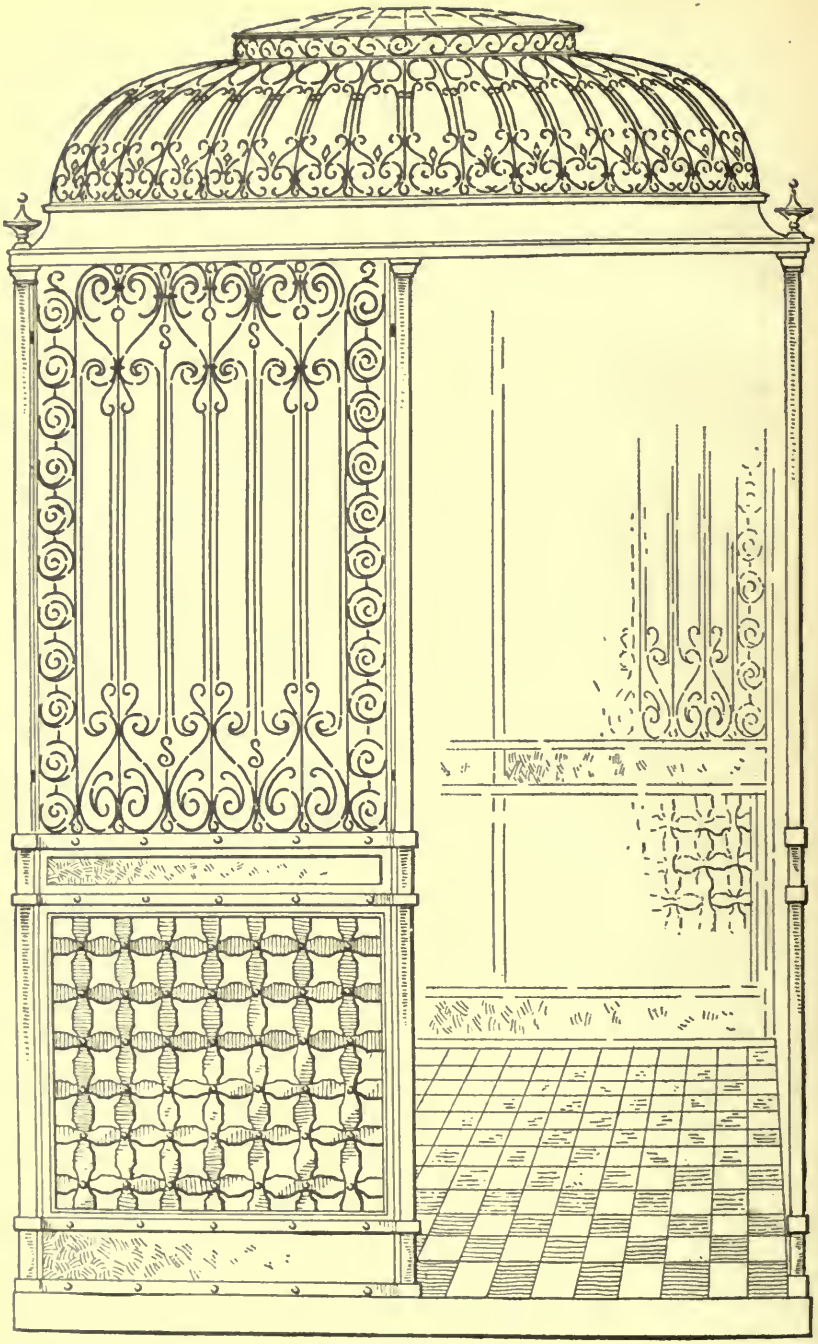


FIG. 77.

iron; the dado is a diaper of basketwork. The grille by the arrangement of the scrolls does away with a border top and bottom, but, as it is divided into three panels having the bars gathered reed fashion, it is necessary that a border be provided to close the space at the sides. The rods forming the reeds are separated by button washers and riveted together. The dome of this car is circular in plan, divided into a series of radiating panels finished at the bottom with a link-scroll design and at the top with rings. The crown of the dome has the scrolls so arranged that they form a natural continuation of the panels.

LEAVES AND FOLIATED WORK.

56. All the work considered up to the present time has been purely structural. Such ornament as has been necessary in elevator fronts or office partitions has been of a conventional character, and is confined to strap-iron grilles. Now, however, we come to the consideration of another kind of ornamental ironwork—the execution of leaves and flowers in sheet and bar iron, by means of forging and working the metal. No machinery is required for this work but man's own ingenuity and skill; however, artistic intelligence and dexterity of hand in the use of simple tools are indispensable in the production of satisfactory results.

In this branch of wrought-iron work, the designer must be intimately acquainted with his material; he must know how much working his metal will stand under certain conditions, and how much working his design will require to bring it into shape. He must know at what point and under what conditions forging will be necessary, how much of the work can be formed cold, and what details will have to be executed with the metal at a red or a white heat. Wrought-iron leaves are usually executed in sheet metal and hammered into shape; flowers sometimes require both sheet and bar metal; while designs of foliated grille-work require sheet, bar, and strap iron in varying quantities, according to the character of the work.

57. In Fig. 78 is shown a finished leaf as it would appear when placed in the position it was to permanently occupy. To reproduce this leaf in iron, it will first be necessary to make a developed drawing of it—that is, a drawing of the leaf as it would appear if flattened out to the original shape of the metal when first cut out, before working in any manner. It is hardly possible to lay it out exactly—and, in fact, such accuracy is not required, as, the general dimensions being correct, the other parts may be worked into shape in subsequent operations. In Fig. 79 is shown the general appearance of the developed drawing. This drawing should now be carefully traced on the sheet metal and cut out. The crude iron leaf is then placed upon a block of soft metal, such as lead, and cold hammered into the general shape required. As constant hammering is likely to make the metal brittle and hard, it is sometimes necessary to anneal the iron in the forge several times before the leaf is finished. Special forms of hammers are used to shape the work, two of which are shown in Fig. 80. The one at (*a*) is flat on both faces, and is used in the general shaping of the leaf; while the one at (*b*) with its spherical head is used to produce the curves of the lobes and indentations, and to bring the leaf to its finished form. The flared face opposite the spherical head is brought into service when sharp indentations or veins are to be expressed, though other tools and punches are used in connection with the work for this purpose.

FIG. 78.

FIG. 79.

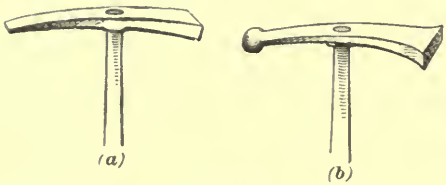


FIG. 80.

58. In designing leafwork for a grille, a gate, or a railing, consideration must always be given to the appropriateness of its position in accordance with the utility of the device and the architectural style of the building. For instance, in the elevator cars and enclosures heretofore discussed, we have given little or no consideration to wrought-iron leafwork, because an elevator is essentially a utilitarian device, and such ornamental features as we express in its design should be a part and detail of the necessities of its construction. The grilled sides of the elevator are rendered ornamental simply by twisting the iron straps and bars of the frame filling into geometrical forms; but where a grille is inserted in a transom light, or over a gateway, simply as a finish and ornament to the opening, the design may be elaborated with leafwork, as the purpose of the grille is not utilitarian but ornamental. Again, the heavy gates of a carriage entranceway require some leaf decoration to harmonize with the design of their surroundings, but they must at the same time preserve their identity as a purely utilitarian detail. The leaves and tendrils must not be delicately modeled in thin metal, but must be boldly hammered from sheet iron of from $\frac{3}{32}$ to $\frac{5}{32}$ inch in thickness. There must be no feeling of frailty in such a detail, and the ornament must be as strong and serviceable as the main structural details of the gate.

59. In Fig. 81 is shown the design of a panel suitable for a light railing, or a protecting grille over a glass screen. The lines of the design are too delicate to permit of its use in a position where it would receive hard usage, and its details may therefore be of very light materials. The main framework, it will be observed, is composed of substantial bar iron, while the filling and leafwork is of very light gauge. The treatment of the panel shown in Fig. 82 is the reverse of this. Heavy framework filled in with substantially proportioned scrolls and bars forms the general scheme of the design, while the leafwork is applied to the parts where the scrolls unite, and thereby render the points of

forging more pleasing to the eye. The leafwork in this design plays no part in the structural strength, but renders the structural necessities artistic, by combining and uniting them under an artistic form.

These two examples, Figs. 81 and 82, are intended to show the two principal conditions to be met in leafwork design. Fig. 81 shows a framework full of ornament, possessing little strength and mainly intended for appearance. Fig. 82 shows a strong frame and rigid grille-work, certain

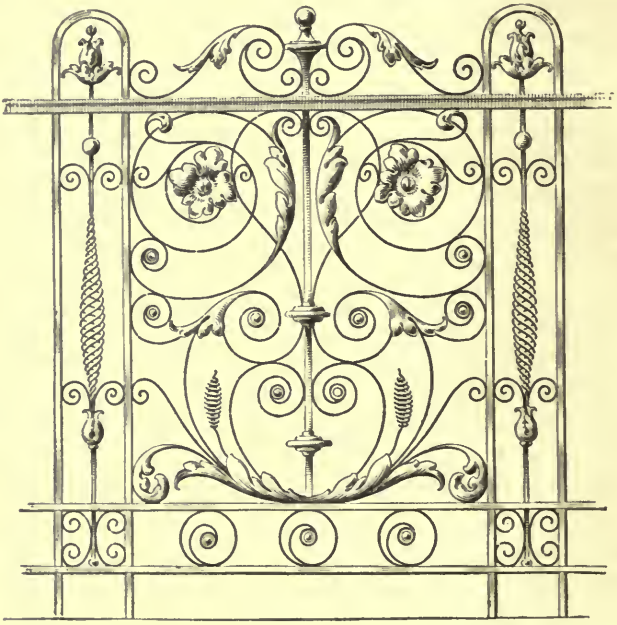


FIG. 81.

details of which are *emphasized* with leaf design. In Fig. 82, strength is the main consideration, and the ornament clothes the utilitarian details in artistic forms.

60. In Fig. 83 is shown a piece of wrought-iron work which exceeds, in elaboration of design, anything heretofore considered. It is a design for one panel of a railing, and is intended to be supported at each end by a heavy stone pier or post. The top rail *a* and the bottom rail *b*

extend from one of these posts to the other in an unbroken line, while the inner rail *c* is broken by the lines of the main scrolls, and is worked into a fret design in the corners.

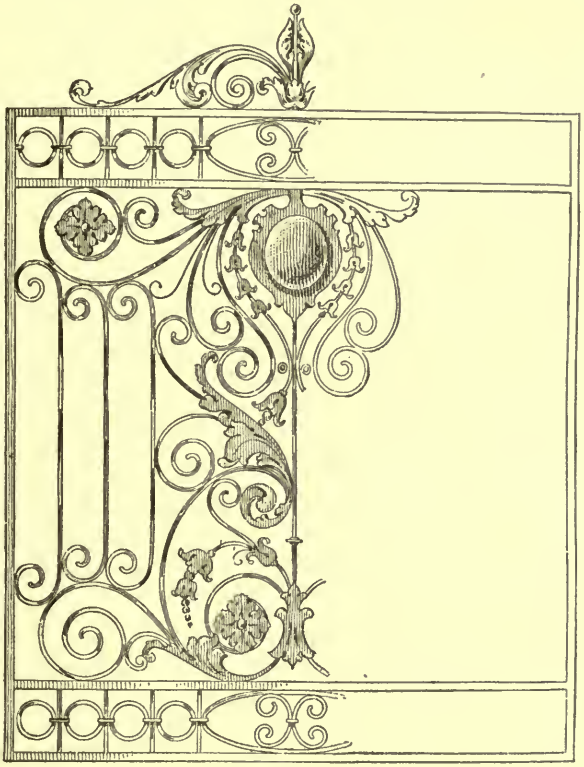


FIG. 82.

As the filling of this panel is nearly all leafwork, it follows that the leaves should be wrought in a heavy gauge of iron. The delicacy of the design will in no way be impaired by such treatment, as the parts must possess an appearance of strength sufficient to fulfil their several functions.

The main lines of the ornament in this design are composed of heavy iron bars, to which the leafwork is secured by forging. The double lines of the large scrolls forming the scheme of design at each end are filled in with a fret

ornament of light iron. The iron of the main scroll being wider than that of the fret, the latter is protected from injury, but is raised from its support on button washers, in order that it may be more readily seen. The same may be said of the guilloche ornament on the left side of the center scroll, but the stem-and-bud ornament on the right side of the centerpiece is bent in place independent of the surrounding bars.

FIG. 83.

The leafwork is forged to the structural details as shown, and therefore seems to form a natural part of them, though the style of leaf is of an exaggerated system of design which is not highly artistic from a strictly architectural standpoint. The example serves to illustrate, however, the extremes to which wrought-iron-work designs may be carried, and the tasks which a skilful workman may be called upon to carry out. Fig. 84 shows another design which, though less ornate in its leafwork, is equally complex in the arrangement and management of its scrolls. The main scroll lines break and change their direction suddenly, thereby leaving some points improperly secured, and necessitating other scrolls to secure them in place. The centerpiece is executed entirely in sheet metal, the drooping leaves being secured to the surface of the vase with rivets. The main leaf of the scroll on the right-hand end of the rail is somewhat similar to the one shown in

Fig. 78, though larger. In this position it forms an ornate

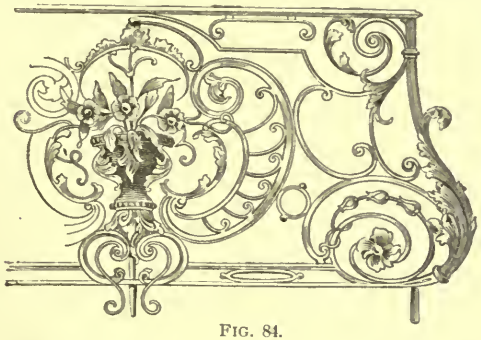


FIG. 84.

finish to the panel, and at the same time serves as a floral calyx out of which the lower lines of the scroll appear to naturally grow.

FORGED WORK.

61. In the succeeding pages, descriptions of the illustrations given cannot be more than general, as the chief object is to give examples which are standards of artistic and ornamental design. Instruction of the student in smithwork has not been attempted, nor has it been deemed advisable to try to cover the complete field of useful and ornamental objects made in wrought iron, but to discuss only a small number of the ones more commonly seen and used in house building. That a knowledge of the tools and the methods employed in working iron may be made known to the student, and that the designs shown may thereby be better understood, the following short description is given: The few primary tools consist of a forge, an anvil, a pair of tongs, an ordinary blacksmith's hammer, a fuller, a set of punches (say, three sizes each of square and round), three swage hammers, a set hammer, a flatter, and a riveting hammer. The fuller and the swage hammers are usually called *top* swages, as a duplicate of the hammer face, which fits in a hole in the top of the anvil, is called a *bottom* fuller or swage. The making of grilles and scrolls by bending and

riveting is described under another head. Any two or more parts joined while hot are called *welded*, and all objects worked from a single piece are called *forged*. Whether welded or forged, the iron must first be brought to a white heat, and work commenced with the metal at this color, and continued until the iron assumes a deep cherry red, although, of course, this will somewhat depend on the grade of iron used. When the object to be welded or wrought is placed on the anvil, the blows at first should be light, and gradually increased in force as the metal cools, or the forging is likely to be knocked needlessly out of shape. To convert a section of a flat bar into a round one, the bar is brought to the proper heat in the forge fire and then laid across a bottom fuller set in the anvil, where, with a pair of tongs, it is held edge up, with the fuller hammer on the upper side. In this position it is indented until the approximate size of the round is made. The bar will now look as though it had a nick cut out of it on each side, the space between being the guide for the round part. The bar is now again heated, and a bottom swage put in the hole in the top of the anvil, and the bar is placed on the anvil and worked to a rough round. It is then once more heated, and this time placed in the bottom swage, the smith holding the top swage in place, while the helper strikes the top of it repeatedly as the bar is drawn between the swages, producing an even smooth finish. In the case of a fence railing or window guard, where the bars or pickets are to pass through the horizontal rails, and it is desired that the rails shall be of a uniform thickness where bars pass through, it is necessary that the rail shall be what is termed *upset*, that is, heated and driven together endwise to produce a bulge at the desired portion; or a small piece may be welded on at the point where each bar is to pass through; the rail is then heated, and the required hole is made with a square or round punch. After reheating, the rail is passed over the anvil, evening up the thickness where necessary, and is then finished with the flatter, to remove all the marks of the other tools. If two bars are to be joined at right angles, they are placed one over the other at a white heat

and welded together with a common smith's hammer, after which the slight bulging at the juncture is worked out. In especially fine work, a small piece is cut from each bar at the point of welding, though this is seldom necessary in ordinary practice. Surface cuts, indentations, etc., for the production of diaper designs or patterns on plain surfaces, should be made at a low heat with fullers set in the bench, or anvil, as the case may require, a guide or spacer being so placed as to keep the work uniform and true. The finials of posts and knobs on fence bars are first roughly forged out by hand, and then placed in a die under a trip hammer; or, where this is not at hand, the die is struck with sledges. When small work is welded, the tool marks are removed by the set hammer, which is simply a small flatter.

62. In making festoons of leaves or flowers, or of both, a stem should first be made of the required length, and the pieces for the leaves cut from thin bar or strap iron, on which the individual stems of the flowers are welded. The shape of the leaf or flower is then worked out on a soft metal block, as described for leafwork. When all the leaves and flowers are made, the main stem and a single leaf or flower are heated in the forge and welded together, this process being repeated with each leaf and flower until all are in place; they are then finished up and put in exact position or alinement after the metal is cold. When an object is to be forged out of a single piece of material, it is heated in the forge and worked under the hammer to the required shape or form; this is the most expensive part of wrought-iron work.

GATES AND FENCES.

63. Most of the examples heretofore given have been of light work that could be made without heating the iron, but in Fig. 85 is shown a piece of a more substantial character. The main bars are $1\frac{1}{2}$ inches square, the cross bars are 3 in. $\times 1\frac{1}{2}$ in., wide enough for the uprights to pass through, and the scrollwork is of $\frac{1}{4}'' \times 1''$ material. When

a bar is to be punched out, as in the horizontal members in this case, there should be ample metal left on each side of the hole punched to prevent the sides from spreading under the pressure of the punch and leaving the bar somewhat protruded at these points. The scrolls are alike in the lower part of the gate, and are secured to the upright bars by a narrow strap on one side and a countersunk screw on the other. The hinge or hanger should be arranged at the top and made as shown in Fig. 86. The frame of the gate, which is a square bar, is rounded where the hinge clasps it, as shown at (*a*). The jagged part of the hinge is embedded in the stone piers or wall to which the gate is to be hung, and fixed in place with molten lead; or, where circumstances will permit it, the bar is passed entirely through the wall and secured on the other side with a large washer and nut. The gate is held by the clasp, which is secured with two bolts passing through the hinge bar, as shown at (*b*).

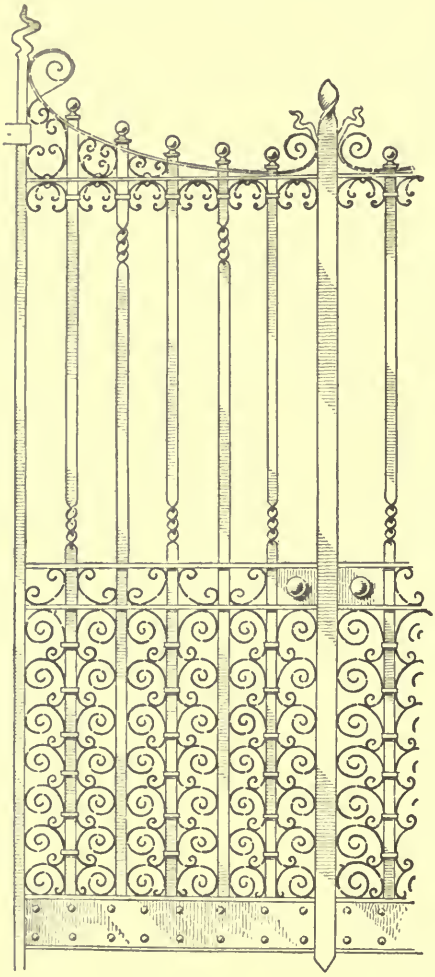


FIG. 85.

In exceptionally high-grade work, the inside of the hinge is lined with a brass collar, as shown in Fig. 87, which prevents the two surfaces from rusting when they are in contact. Nearly all gates, and especially heavy gates, are pivoted at the bottom; and the pivot is usually formed at the lower part, or *heel*, of the gate itself, and fits in a socket under the gate. The objection to this method is that the socket is likely to fill with dirt, and the gate become difficult to move. A better way is to make the socket part of the gate, and

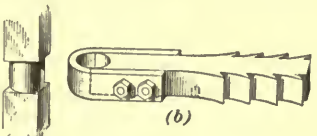


FIG. 86.

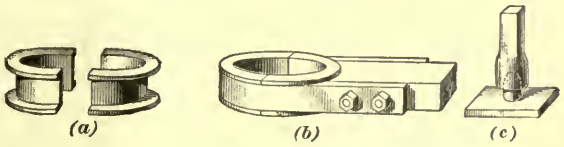


FIG. 87.

have the pivot separate, as shown in Fig. 87 (*c*). An oil hole may then be bored through the socket in an oblique direction to the pivot, which may then be oiled; and, as the socket is in the gate, the dust and dirt cannot get in and clog it up.

64. The railing shown in Fig. 88 is a good example of forged work, and illustrates the application of leafwork without detracting from the lines of the fence. The main uprights and the horizontal rails are clearly defined, and, as they should be, much heavier than the bars and scrolls filling the panels formed by them. The fence is divided into large panels or sections, one a double gateway. The first two upright bars at each end of the panels are carried up, forming posts, and an increase in the size of these bars would be an improvement and further emphasize the post effect. The top of the post is finished with a finial ornament, and the gate as well as the side panels are finished with a cresting. The cresting of the gates is arranged to group them as one panel, and the main scrolls are decorated

with leafwork. The top and bottom of both the gates and panels are well braced with an open rail having a scroll let in between. The scrolls filling the top and bottom of the panels are finished with a leaf-and-bud ornament, and the bars are braced by three rows of rings secured with straps and screws. The posts from which the gates are hung are

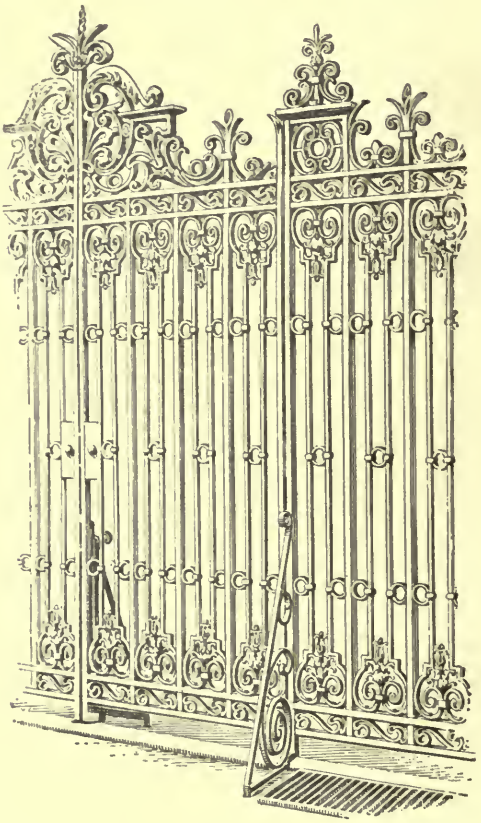
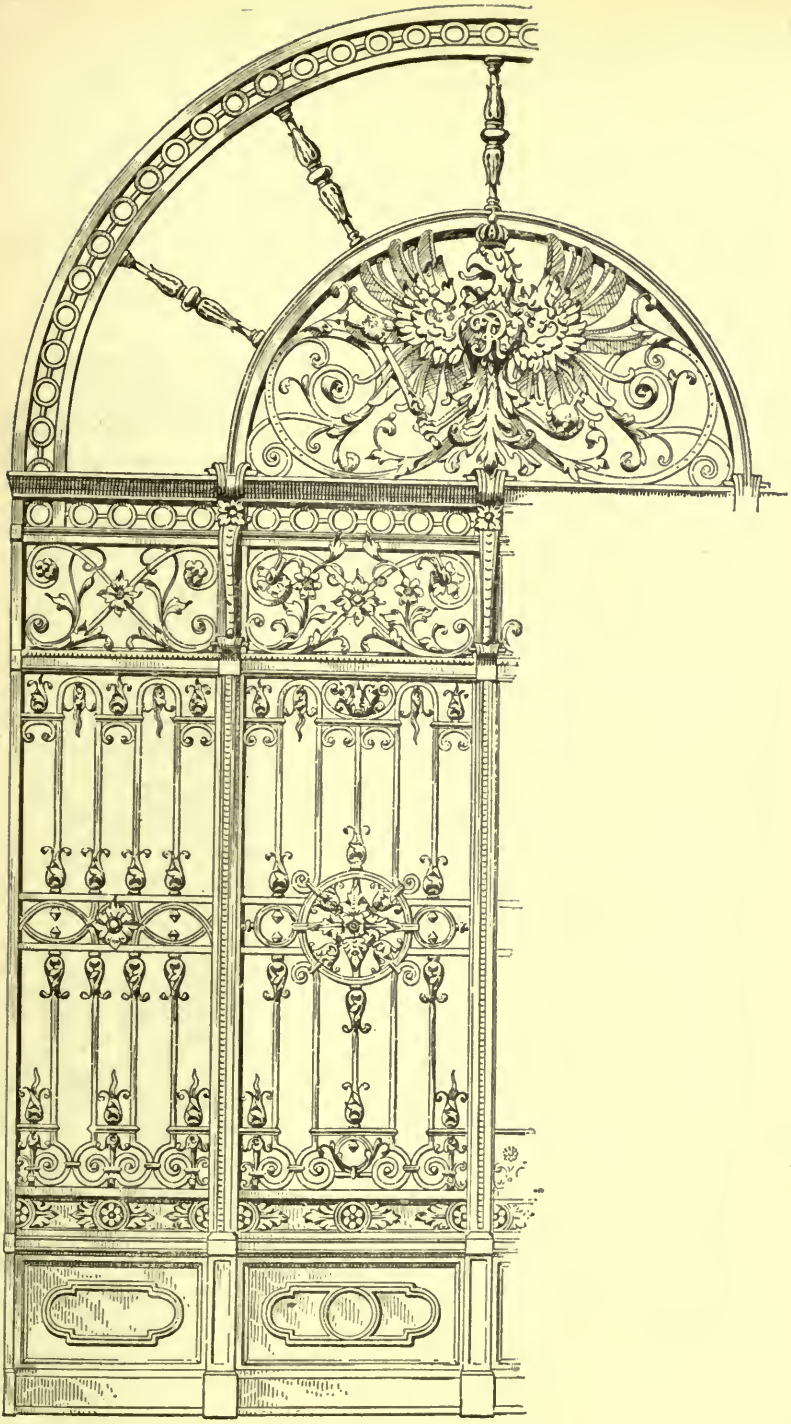


FIG. 88.

braced with triangular foot braces, and these as well as the posts themselves are leaded into the stonework, while the post next the column is secured with expansion bolts. The gate shown at Fig. 89 is a vigorous, well balanced design, decidedly German in character, and including in the design



3-11

FIG. 89.

of its transom the German national emblem. The side panels of the screen, as well as the outside of the transom, are open and less elaborate than the central panels, the contrast between them heightening the effect by separating the rich carving which existed on the stone architrave from the elaborate iron grille of the center. The transom bar is in four panels, each of which is filled between the border frame and lower rail with grille-work composed of crossed scrolls and decorated with leaves and rosettes. The continuation of the principal vertical lines from the screen to the transom bar is accomplished by a console bracket, the top of which clasps the transom-bar rail. A point in this design which might be improved is the manner in which the inner frame of the semicircular transom border is carried down past the top of the transom bar to the border frame, thus giving the idea that the transom frame is supported there; the omission of this piece of frame would considerably heighten the border effect and remove this weak appearance.

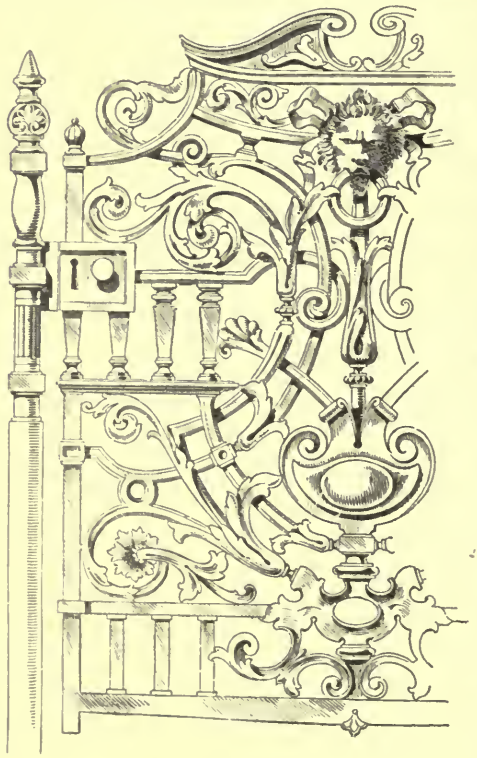


FIG. 90.

65. At Fig. 90 is an example of a small garden gate in cast iron, and with the exception of the central shield and the ornament at the top, all the

members are kept approximately the same general thickness, to avoid any danger of cracking during the cooling

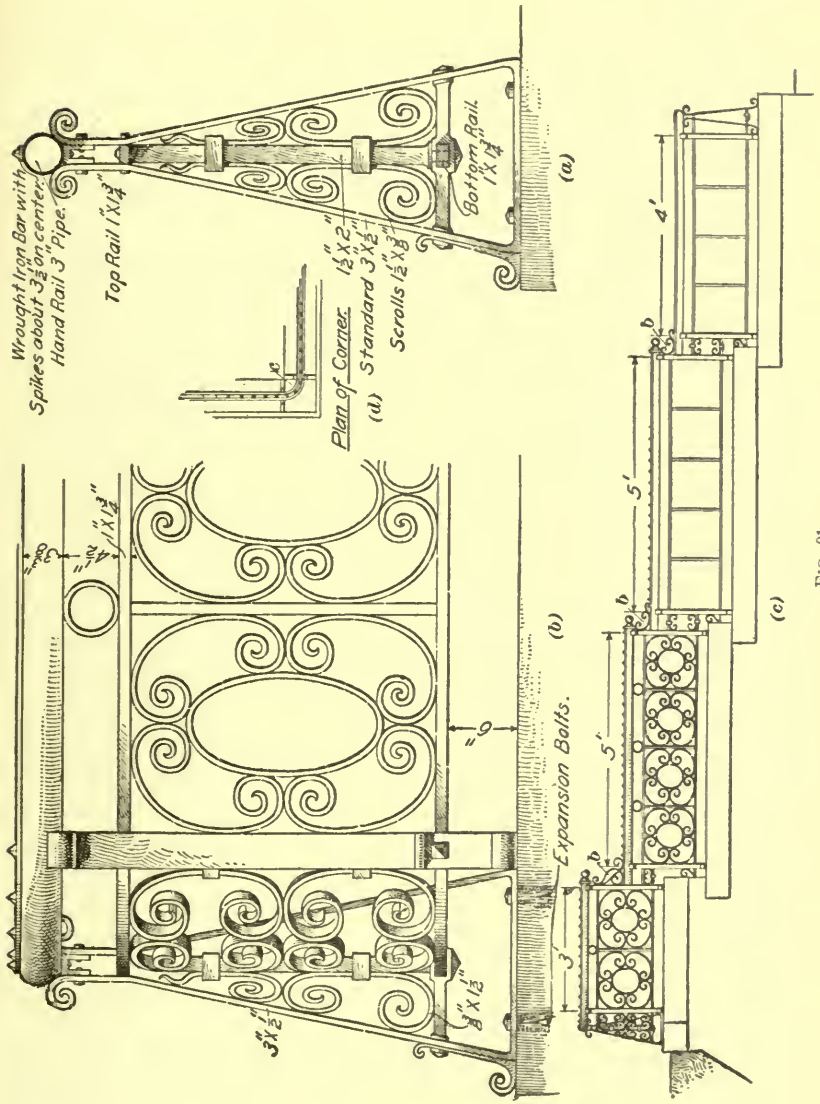


FIG. 91.

stage. The parts that appear heavier on the face are thinned out to preserve the balance of metal. Cast iron for small work of this kind is inferior to wrought, as the effect of contrasting heavy and delicate features is somewhat wanting, owing to the limitations of the material. The railing shown at Fig. 91 is a very massive one, and still the proper thought has been given to the different members. The posts or supports are made triangular in shape, as shown at (*a*), and would almost retain their position without the aid of the expansion bolts by which they are secured to the coping, as shown at (*b*). This railing tops a stepped coping, as shown at (*c*), and is joined by easy and graceful scrolls at the point of step *b*. The corners are arranged as at *c* in the plan (*d*), and the grille bent to the radius formed by the intersection of the supports at their bases. The hand rail is a wrought-iron pipe finished at the ends with a knob ornament, and the top has a bar studded with spikes to prevent lounging upon it.

WINDOW GUARDS.

66. A window guard should be primarily a protective device, and secondarily an ornament or decoration. As a rule, especially in private-residence work, the design of these very necessary appendages is not given a proper amount of attention, but they are certainly as deserving of mature consideration as any other ironwork of the structure. They may be made to form the divisions of the window opening in place of the bars of the sash, and to produce the desired effect of window subdivision, at the same time leaving the glass in any required size. It is not necessary that a window guard shall be flat, nor set out of sight when looking towards the window from the street, but may be a roomy addition to the window sill, where in summer flowers may be placed to blossom in the sun and protected from high winds or careless hands. Small openings for ventilation or light may be rendered pleasing by simple and effective guards, such as those

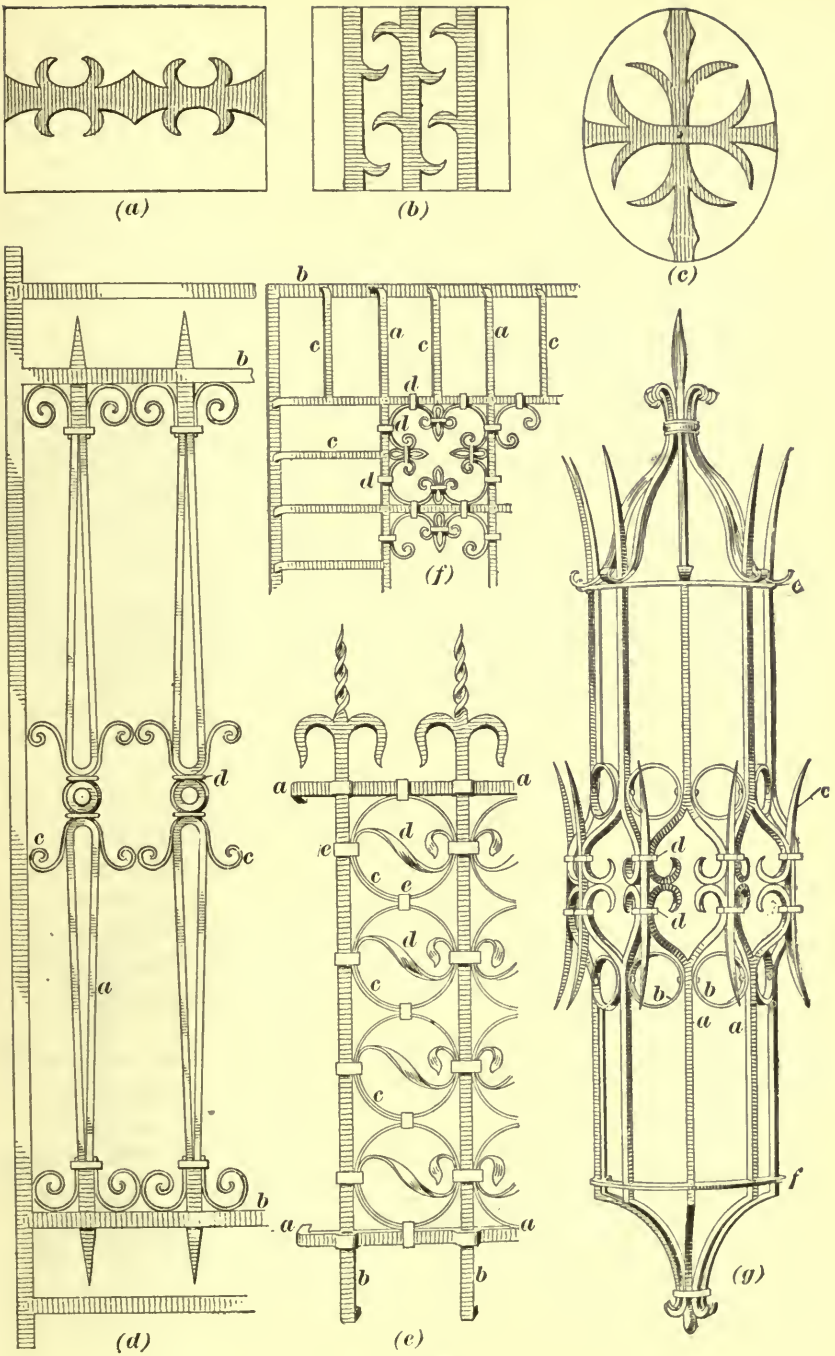


FIG. 92.

shown in (*a*), (*b*), and (*c*) in Fig. 92, cut out of single pieces of iron. The guard shown in Fig. 92 (*d*) is a clever piece of forging, and illustrates what simple and yet refined design may be executed in this class of work. The upper and lower parts of the bars *a* are made by bending the iron into long open loops as shown, the ends being carried through the rails *b*, a ring forged between the two interior ends, and the scrolls *c* forged to the bars and ring; the clip, or clasp, *d* encircles both ring and scroll, and binds them together. The design shown in Fig. 92 (*e*) is very old in style, and is made to set over the jambs of the opening, the rails *a* and bars *b* being provided with return ends which are let into the stonework about 6 inches from the edge of the window. The rings *c* forming the grille in this design are carried about a quarter-turn past the full circle, and the iron is twisted and flattened out in the center to form a leaf scroll *d*, which, with the rings and bars, is held in place by the flat clips *e*. The bars are drawn out and cut in three prongs at the top to form a cresting, the center one being twisted, and the other two bent down to give ample protection to the top of the opening. The design shown in Fig. 92 (*f*) is constructed for use either on the wooden window frame or on the face of the wall surrounding the window. The bars *a* forming the large square mesh are welded together, and extend beyond the mesh a distance equal to its width, and are then bent back 4 inches and welded to the frame *b*; intermediate pieces *c* are set between them, and a border is thus formed. The angles of the mesh are filled with scrolls as shown, which are held in place with flat clips *d*.

67. The guard shown in Fig. 92 (*g*) is an example of how effectively iron may be employed in decorating an otherwise plain opening, and transforming it into one of the attractive features of a house front. This guard is intended to cover a small window opening, which would almost escape observation without it, and certainly add nothing to the design of the building, though necessary for lighting the interior. The guard in Fig. 92 (*g*) is made up entirely of

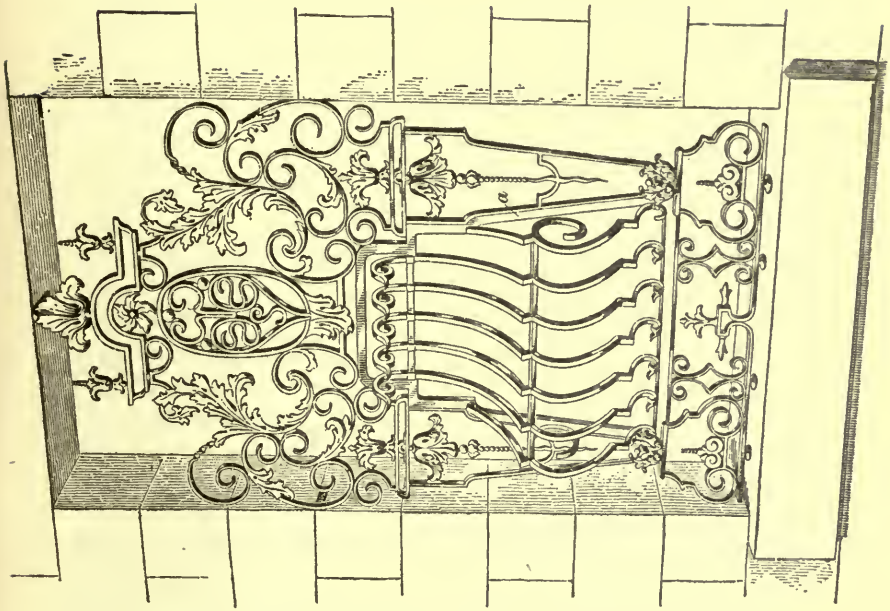


FIG. 94.

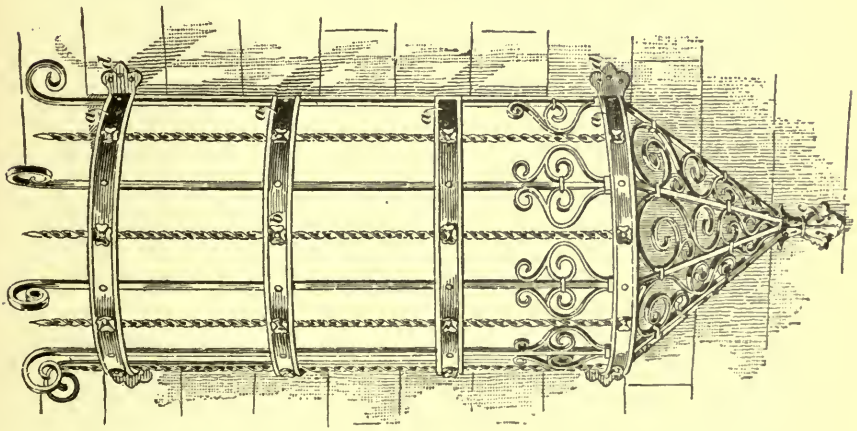


FIG. 93.

different sizes of bar iron. The principal features are the manner in which the bars *a* are divided just above the circles *b* which are riveted to them, the divided portions being wrought into scrolls, which are welded to the spikes *c*, and are further bound by the strap clips *d*. The tops of the bars are finished with spike points, passing through a band *e* and through the bars forming the top, and are welded together. The guard is attached to the opening by the ends of the bands *e* and *f* bent to form lugs which are leaded into holes cut for them in the stone jambs. In the guard shown in Fig. 93, the horizontal bands *a* not only greatly increase the protection, but by the ornamental studs or rosettes on their faces add much to the decorative effect. These studs *b* are riveted on over each twisted bar. The edges of the bands are turned over, forming a border or flange, strengthening and giving them a finish. The twisted bars terminate at the lower band, and the plain bars are carried down, all meeting in a point where they are welded together and covered at the junction with a leaf ornament *c*. The twisted bars are pointed at the top, and the plain ones finished with a scroll. The entire lower portion of the guard is filled with a scroll grille, and a dado of scrolls is filled in between the bars above the lower band. The guard is secured to the stone with expansion bolts let into the stonework back of the ornamental bolt plates *d*.

68. The design shown in Fig. 94 has many points in its favor from both a structural and an ornamental standpoint. It is constructed almost entirely of forged bar iron, with just sufficient leafwork to relieve the monotony of single lines. The design is so open that the interference with light, ventilation, or outlook is inconsiderable; but at the same time it is strong, secure, and amply adapted to its prime purpose as a *guard*.

The presence of the leafwork in the upper part gives it an appearance of lightness and delicacy, but observation will show that behind these leaves heavy wrought bars give the strength which the purpose of the device requires.

LAMPS AND BRACKETS.

69. For exterior and interior lamp posts and brackets, wrought scroll-and-leaf work lends itself most readily. There is no detail of house furnishings wherein wrought iron can be put to such effective use in decoration as in electric and gas fixtures. The necessary presence of the wire conduit or gas pipe forms the purely utilitarian element of the design, and is so easily disposed that the designer may devote nearly all of his energies to the perfection of the ornamental details and the grouping in the composition. It may be well also to remind the student that another consideration than the ironwork itself materially affects this style of design, and that is the forms of electric lamps and globes, with which the fixtures are to be furnished. Electric lamps may be obtained in all sizes and styles, from the large 300-candle-power strictly for commercial use to the small single and half candlepower globes used for decorative purposes. The latter are frequently mounted on the end of white-glass tubes blown in representation of wax candles, a number of which are grouped in one candelabrum or bracket, diffusing the soft unobtrusive glow of old-fashioned candle light, without the offensive grease, smoke, or smell. Again, these same diminutive lamps are enclosed in china globes representative of various flowers, such as the rose, lily, morning glory, etc., and the bracket which supports them is correspondingly designed to suggest the details of the foliated bush or vine.

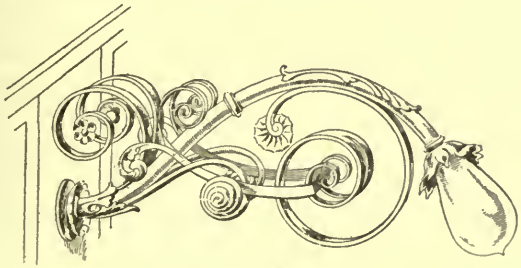


FIG. 95.

70. The lamp in most common use is the 16-candle-power size, and Fig. 95 shows the simple arrangement of one

of these globes at the end of a wrought-iron wall bracket. The design is extremely simple; the tube containing the wires extends in a curve from the wall to the lamp. Iron scrolls appear to emerge from the small foliated wall plate with the tube, and help support it on the outside, while the lamp is so set that its light will not cast a shadow of any part of the ornament of the fixture.

Fig. 96 shows a similar design, somewhat more ornate, though precisely the same in principle. The tube or conduit forms, as it protrudes from the leafwork, the main stem of a floral device, from which scrolls branch out at each side, and at the termination of which is the blossom consisting of a 16-candlepower lamp, surrounded by a calyx of wrought-iron leaves.

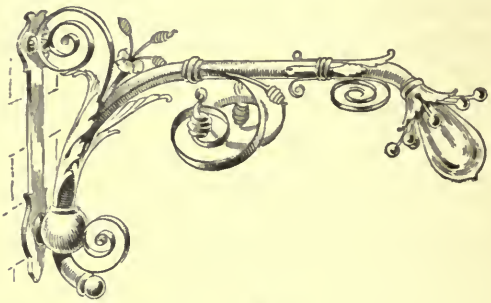


FIG. 96.

The essential points of difference between Figs. 95 and 96 lie in the fact that the former consists almost entirely of strap-iron scrolls, while the latter is primarily a foliated design the scrolls of which exist as a part of the floral composition, and are not, as in Fig. 95, the main scheme of the design. The long wall plate in Fig. 96 renders this bracket much stiffer than the former one, particularly as the scroll on the curve of the conduit tends to tie the wall plate and bracket in two places. The scrolls in Fig. 95 might serve a similar purpose, but not without impairing the effect of a single tube springing abruptly from the wall surface.

71. In Fig. 97 we have a combination bracket designed for both gas and electric light. Here the wall plate is much heavier, and though the general scheme of design is

similar to the example shown in Fig. 96, the leaf and ornamental work is heavier, as is required by the presence of more electric lamps and a gas globe. The main tube or conduit contains both the electric wires and the gas pipe, and as it terminates in a spray of four lamps and one gas jet, it must appear sufficiently strong and well proportioned to carry these details successfully—hence the extra leafwork to give its body bulk and weight, together with the scrolls which appear to support it from above. Behind these is the wall plate which apparently carries the weight of all, and is therefore made bold and substantial in proportion to the work it has to do.

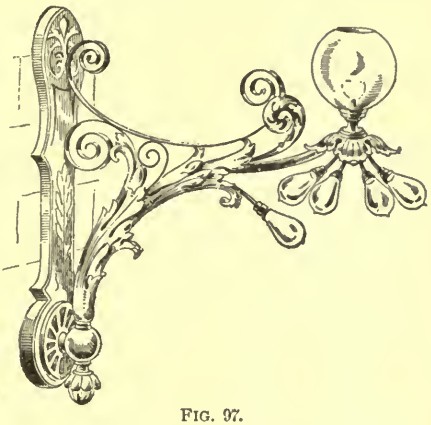


Fig. 97.

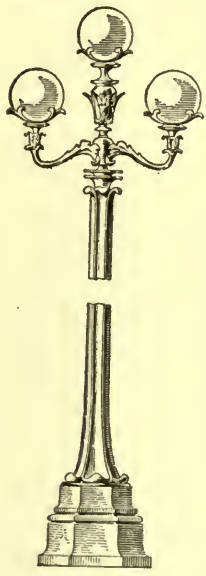


Fig. 98.

72. When gas and electric fixtures are designed for exterior situations, they are usually in the form of posts, though sometimes a wall bracket is desirable, and occasionally a pendant from an archway. Fig. 98 shows a form of lamp post, the design of which is suggestive of a giant candelabrum. The base and shaft of cast iron are octagonal in plan, and support the three spherical globes containing the electric lamps. The arms supporting the globes are simply designed with just a suggestion of foliated work in the details. The globe may be of opalescent or ground glass, in order to diffuse the light from the electric lamps within, of which there

may be three or more to each globe, according to the illuminating requirements. This style of lamp post is frequently used as a luminant for the porch of a private residence, hotel, or club, but for street lighting where the arc light is used, a different form of post is required, owing both to the difference in the form of the lamp, and to the care attendant upon its maintenance. Fig. 99 shows the style of support suitable for the latter case. It is executed in cast iron, as was the design shown in the previous example, but owing to the difference of its purpose the entire character of the design has necessarily been altered.

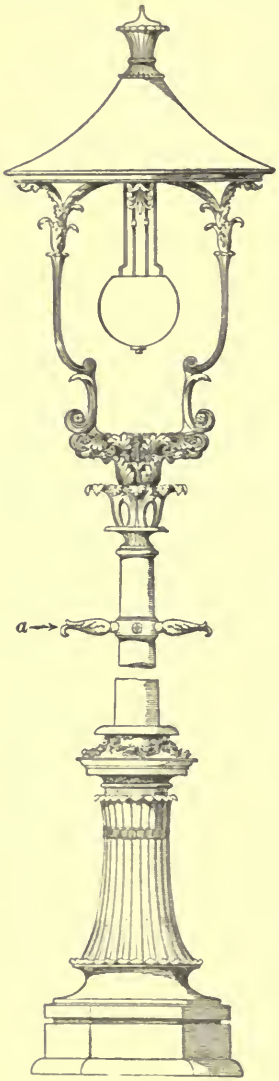


FIG. 99.

In the first place, the post shown in Fig. 99 is much heavier and bulkier than the one in Fig. 98; as, being likely to receive somewhat rough usage from passing vehicles or careless draymen, it must not be so slender as to be easily broken. The upper portion is designed as a loop or wicket, in which the arc light hangs under a protective roof or hood. Thus we see that its exposed position requires the street lamp to be heavy and strong, and that the character of the light it carries determines the form of its top, while the maintenance of the arc light requires the two projecting rungs *a* against which the keeper may rest his ladder or upon which he may stand when he adjusts new carbons or cleans the globe and copperwork.

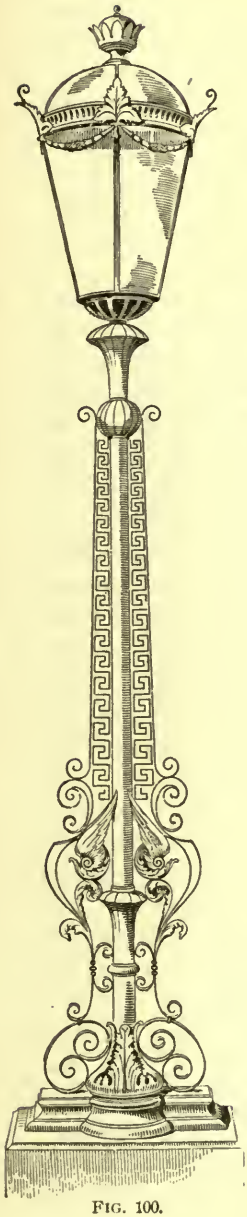


FIG. 100.

73. In Fig. 100 is shown a form of post for a gas lamp. The main shaft or post is of cast iron, on which the fretwork and scrollwork of wrought iron is secured with countersunk screws. The lantern at the top consists of glass plates mounted in a wrought-iron frame which is covered with a dome-shaped hood. This lantern encloses the gas jet or jets and protects the flame from the wind. The scrollwork of this design is so delicate that it is hardly suited for a much exposed position such as a street light, but for courtyards and lawns or for park walks it is admirable, combining delicacy and refinement of design with simplicity and economy of construction.

The lamp shown in Fig. 101 is an elaborate design in cast and wrought iron, suitable as a porch light or as one of a series of lights arranged in a courtyard. The main body is of

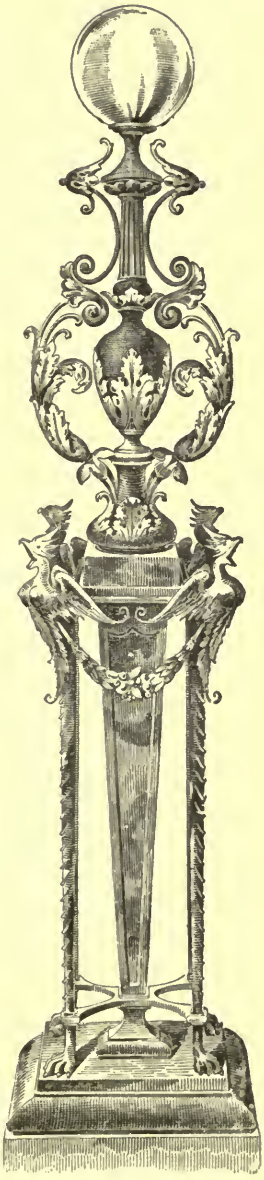


FIG. 101.

cast iron, decorated and relieved with wrought-iron leafwork, secured to the cast-iron standard with countersunk screws. The design is suggestive of an antique, standard, and torch; only, where the flame of the torch would have existed in ancient art, the globe and electric lamp are present here. The globe in this case would be of opal or ground glass, for reasons similar to those stated in connection with Fig. 98.

74. Bracket and gate lanterns of various forms are used on the entrance posts flanking a gate, or suspended over the gate by means of a scrollwork arch. Fig. 102 shows a bracket lamp, the body of which is sheet iron and glass. The pyramidal sheet-iron roof—or *canopy*, as it is sometimes called—is pierced by eight small ventilators and finished on top with a foliated finial. The scrollwork connecting the lantern to the wall is composed entirely of strap work, and is secured to the masonry by means of expansion bolts. Strength and simplicity are the fundamental principles to be looked out for in this class of work.

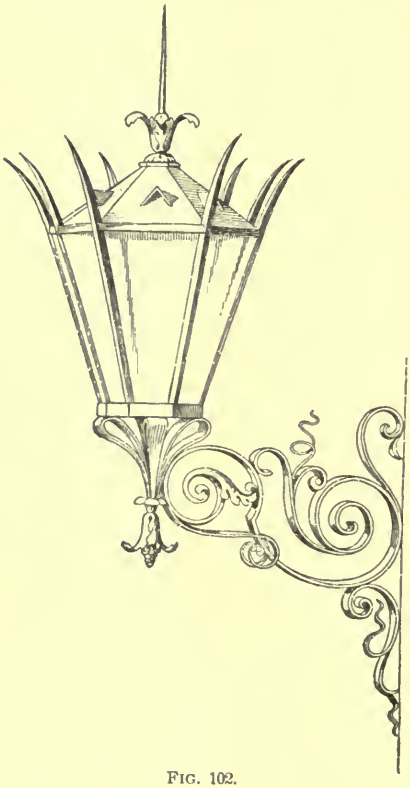


FIG. 102.

The gateway lanterns shown in Figs. 103 and 104 are made of a combination of cast, wrought, and sheet iron. The design shown in Fig. 103 is intended to be placed between the

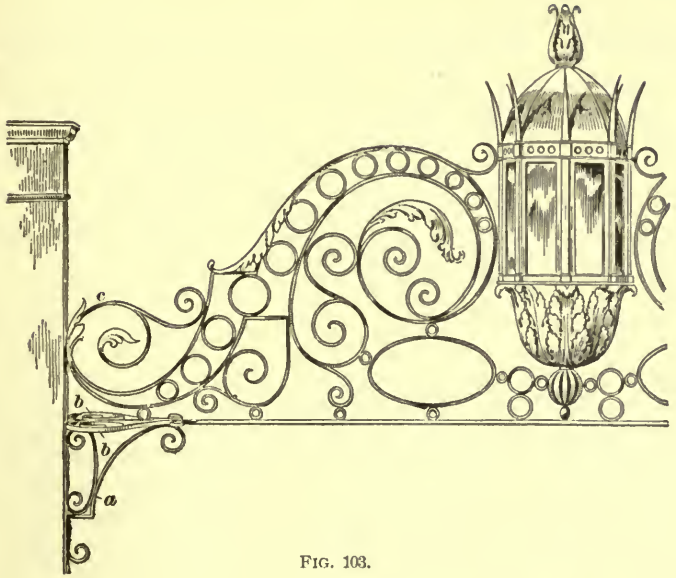


FIG. 103.

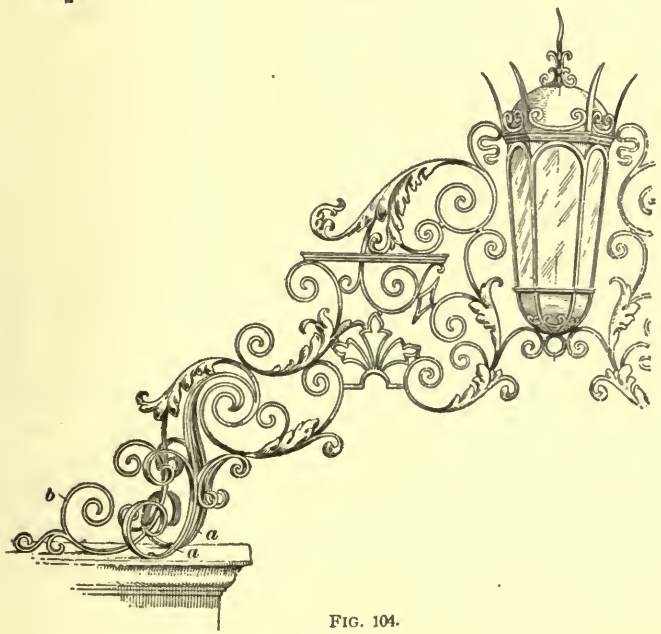


FIG. 104.

gate posts, and is provided with the bracket scrolls *a* to distribute and support the weight, with the scrolls *b* to brace the grille laterally, and with the scroll *c* to prevent any tendency towards a rotary movement. The iron arch in Fig. 104 is designed to rest on the top of the gate posts, and the scrolls *a* are so arranged at the foot of the arch that they prevent any lateral movement or tendency to revolve, the weight being better distributed and also a firmer hold being obtained, by extending the large scroll *b*.

IRON STRUCTURES.

75. It is sometimes desirable to erect small structures entirely of cast and wrought iron. Of these the most common are the small domes or cupolas crowning the roofs of certain classes of buildings, bay windows, oriole windows, and show windows for residences and stores, and occasionally small detached buildings used as offices for the sale of tickets at the entrance of places of amusement, or as an adjunct to some branch of a general service system, as is the example hereafter shown. In any case, the structure is necessarily of an ornamental character, and must accord in design with surrounding conditions.

An example of a detached iron structure is shown in Fig. 105. The entire edifice being constructed of cast and wrought iron framework carrying a copper roof and heavy plate-glass window lights. The purpose of the building is that of a *cab office* in connection with the service of a hotel, club, or theater. The plan is octagonal, as shown in Fig. 106, each angle of the octagon being marked by a hollow cast-iron upright, molded to form the architraves of the window and door openings, and at the same time to contain the T-iron supports *d* of the roof and superstructure. These supports extend to the ground in each case, and stand upon an iron plate, or shoe, as shown at *g* in the elevation, Fig. 105 (*a*), and between them is framed an angle iron, to receive the ends of the floorbeams, as shown at *l* in the

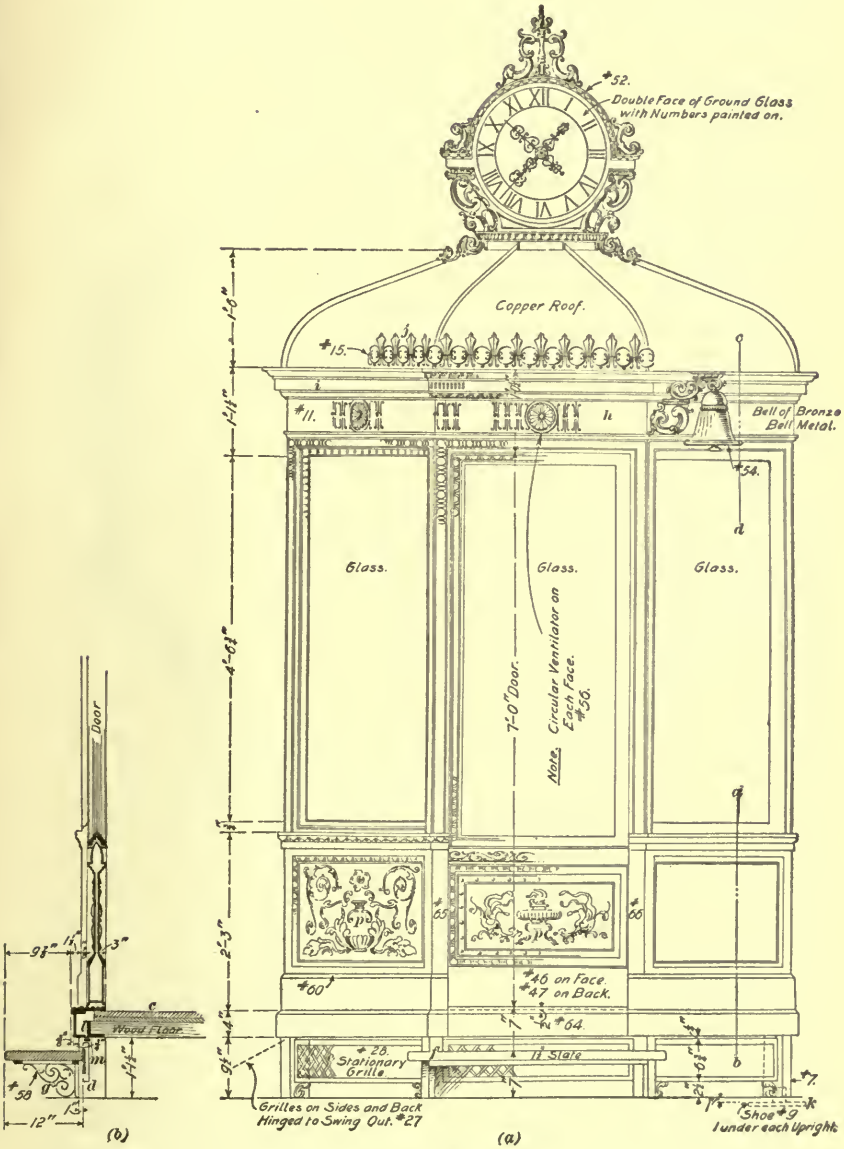

#52.
Double Face of Ground Glass with Numbers painted on.
Copper Roof.
#15.
#11.
Bell of Bronze Bell Metal.
#54.
Glass.
Glass.
Glass.
7'-0" Door.
Note. Circular Ventilator on Each Face. #56.
#65
#66
#60
#46 on Face.
#47 on Back.
#64
#28. Stationary Grille
11 Slate
#7.
#9 Shoe under each Upright.
Grilles on Sides and Back Hinged to Swing Out. #27
(a)
Door
Wood Floor
#58
(b)

FIG. 105.

section, Fig. 105 (*b*). The space from this angle to the ground is filled with a cast-iron grille, as shown in the elevation at *c*;

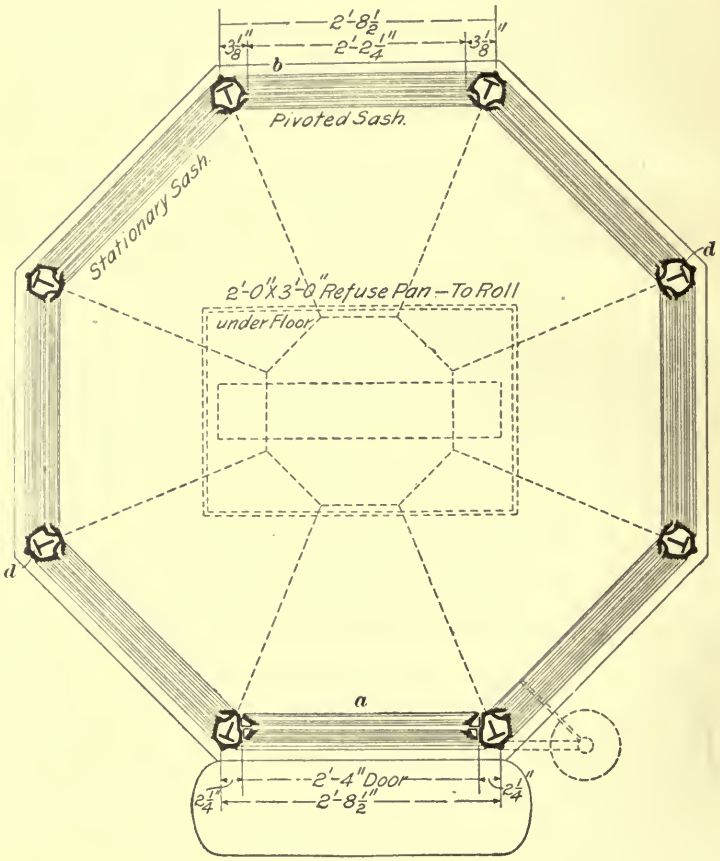


FIG. 106.

while from the floor to the window level a cast-iron plate encloses each side of the octagon with an ornamental panel *p*.

The construction of this paneled dado can be better understood from Fig. 107, which is a section taken on the line *a b* of Fig. 105 (*a*). The angle iron framed between the vertical T's, as shown at *l* in Fig. 105 (*b*), is here seen in section

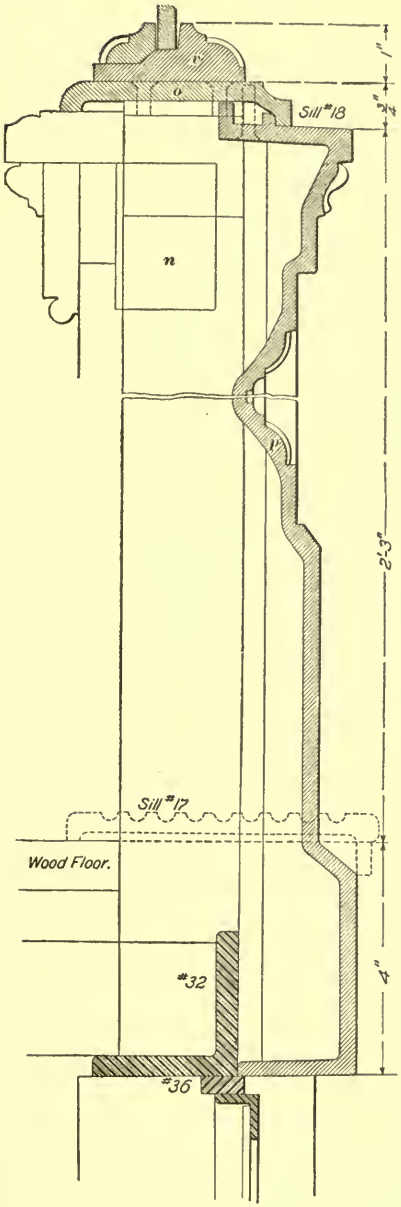


FIG. 107.

as piece #32, and outside of it is the cast-iron facing of the structure, consisting of a water-table 4 inches in height, and the plinth, panel, and window sill extending 2 ft. 3 in. more. The sill cap *o* is secured at each end to angle-iron knees or brackets previously riveted or bolted to the vertical T supports. These sill caps extend over the top of the panel pieces and hold the latter in place by clamping over a rib piece cast on the top of the main panel. On this sill piece *o* rests the sash as shown at *v*, and on the inside of the office is secured the wood trim which forms the finish under the sill.

76. In Fig. 108 is shown a section through the cornice on the line *c d* of Fig. 105 (*a*). This cast-iron cornice is fastened at each end to the T-iron uprights with screw bolts, and thereby braces and secures these uprights at top. The inside cornice *r* is secured

in place by means of the wrought-iron strap *s* bolted to the main cornice, and to which the inside cornice is fastened

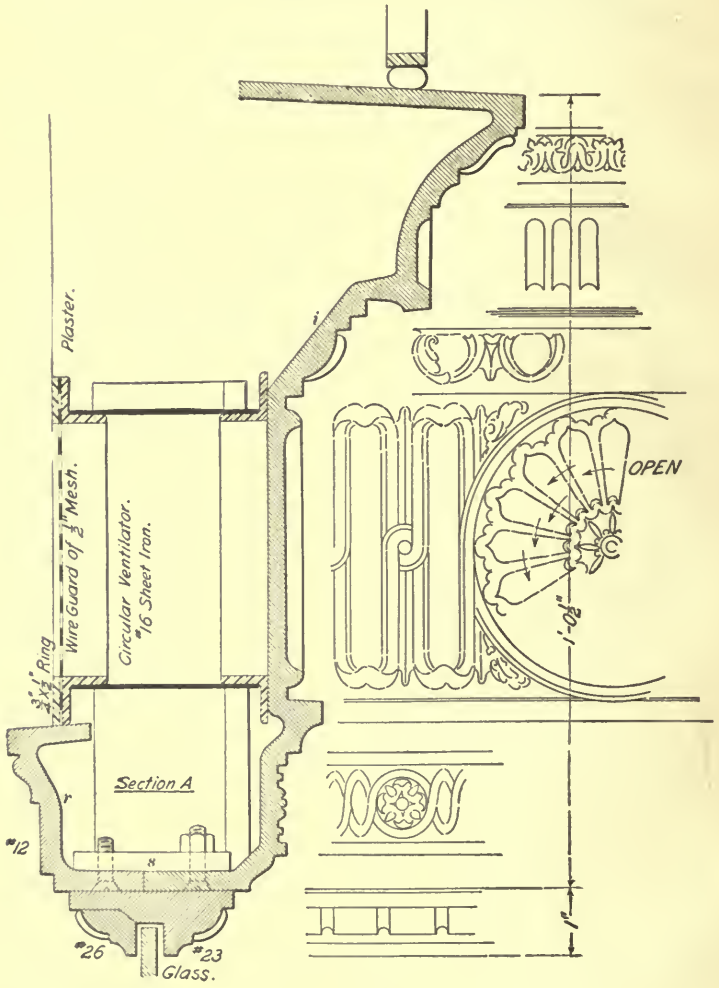


FIG. 108.

with screw bolts. Observe that these screw bolts do not pass through the sash head, but simply secure the two pieces of cast-iron cornice to the strap or bar *s*.

In Fig. 109 (*a*) is shown a section through the lower

part of the cornice where the sash is intended to be immovable.

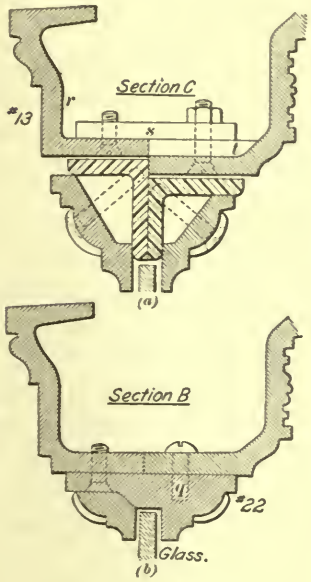
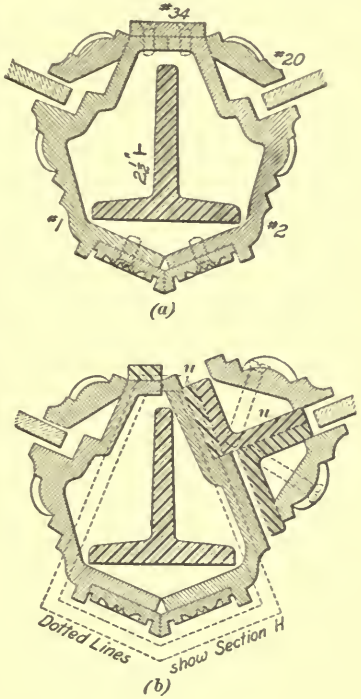


FIG. 109.



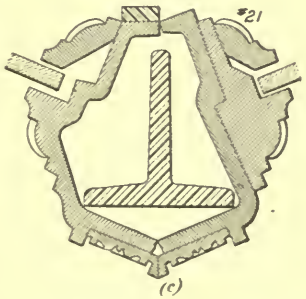


FIG. 110.

The inside or lining strap is omitted in this case, and the outside cornice secures the top of the sash with a round-headed screw bolt, while the inside cornice is secured to the sash head by a countersunk screw bolt, the sash head serving the same purpose here as did the strap piece *s* in Fig. 108. At the door opening, the lower fillet of the inside cornice is omitted, thus permitting the outside cornice to fall below it and form a *stop*, for the top of the door, as shown in Fig. 109 (*b*). An inside strap or bar

s is then used to screw these cornices to, for the preservation of their alinement, while the ribs *t* cast on the exterior cornice maintain it in its proper position as a door stop.

77. The door frame is formed of two angle irons, whose legs are unequal, as shown in Fig. 109 (*b*). This inequality permits the inside angle to extend beyond the exterior one, and strike (when the door is closed) against the door stop formed in the architrave or jamb casting.

Fig. 110 shows three sections through the architraves and supporting **T** irons of the main frame. At (*a*) is shown a section through the architraves of the fixed sashes, where the glass of the windows is held in place by a molding and recessions in the casting. At (*b*) the section shown is through the architrave at one side of the door, where provision is made in the casting for the door stop against which the longer-legged angle iron of the door frame shall strike, and at (*c*) is shown a section through the architrave at the side of a pivoted window sash. The glass is here shown secured in the cast-iron sash frame similar to that in Fig. 108, except that in this case a rebate is cast in the frame and jamb against which the sash may strike when closed, and thus be prevented from revolving past the architrave.

78. The roof is framed with light angle irons bent to the form shown in the elevation, Fig. 105, and covered with copper on the outside; while the inside or ceiling is plastered on wire lath. The cresting around the eaves is of simple strap iron, a detail of which is shown in Fig. 111. The clock face is framed in a cast-iron ring with ornamental scrolls as shown, the details being similar to other cast-iron ornament of this character heretofore described.

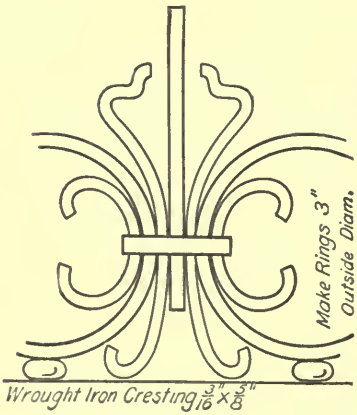


Fig. 111.

ROOFING.

HISTORICAL INTRODUCTION.

1. The origin of house roofing is to be found in the endeavor and determination of man to provide for his physical wants and comforts. Man, in a primitive and uncultivated state, commenced by rudely imitating birds and beasts in his attempts at shelter seeking and self-protection, constructing or appropriating caves, or building arbors of twigs and branches. The hunter had recourse to the cave, the nomad to the tent and bower, while the agriculturist built himself huts of dried turf. The skins of beasts preceded the tent and the tent developed the bell roof of the Chinese and Tartars. See Fig. 1.

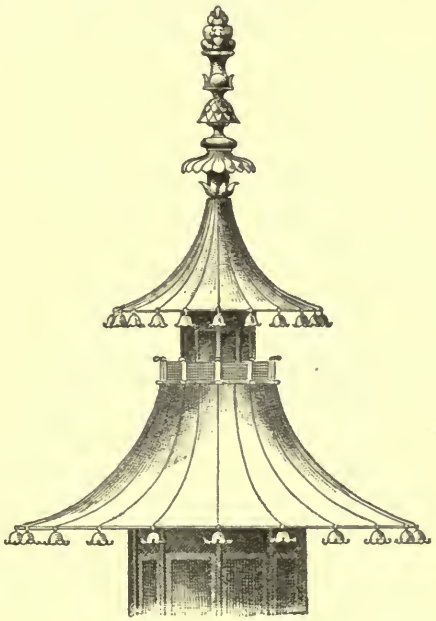


FIG. 1.

2. Tents.—The skin tent was much used by the Arabs, and was generally made of goat's skin, dyed black, spread over two or more poles about 8 or 9 feet long.

The Australians, the tribes of the Polynesian Archipelago, the Caribs, and the nomad tribes of North and South America were tent dwellers.

3. **Huts.**—After the tent, came the hut of wood or stone.

FIG. 2.

The construction of the stone huts, or beehives, so called from their shape (see Fig. 2), was a combination of both house and roof, and may still be found in England, Scotland, Wales, and Ireland. It is supposed that this period was followed by the cliff and the lake dwellers. The former hewed out caves in the cliffs to form a covering to protect them both from the weather and from the attacks of enemies.

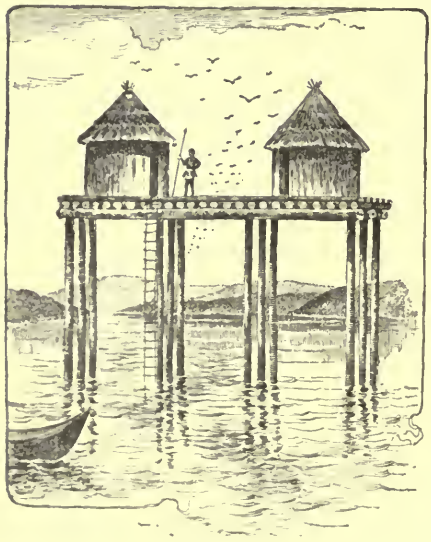


FIG. 3.

The lake dwellers seem to have been imbued with similar purposes, for they cut down trees, which they drove into the bottom of lakes, and upon these built huts with

thatched roofs (see Fig. 3). The lake dwellers' huts were very picturesque and mostly found in Italy, Sweden, Switzerland, and Ireland. In Mexico, in South America, and in African regions, there are yet numerous colonies of lake dwellers.

The most noted cliff dwellers' works are in Morocco, in the Old World, and in Arizona and New Mexico, in the New World.

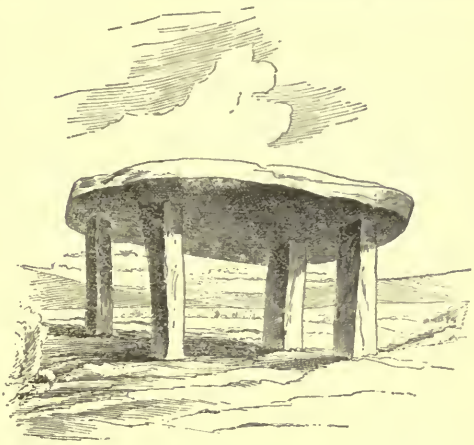


FIG. 4.

4. Stone and Earth Roofs.—The next form of covering was probably that of large stones or monoliths, over which flat stones were placed (see Fig. 4). In connection with stone roofs we note also the device of corbeling out each course on the two opposite sides, until they meet at the top. See Fig. 5.

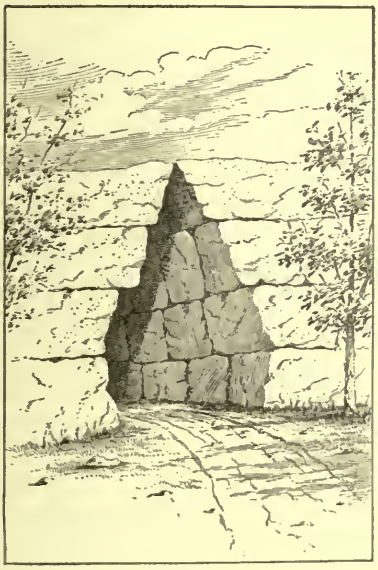


FIG. 5.

The first real roof covering, after the thatch and bough roofs of the nomads, was erected by the Assyrians. These were built of squared timber placed close together and the upper surface covered with thick layers of earth (see Fig. 6). These roofs are said to have

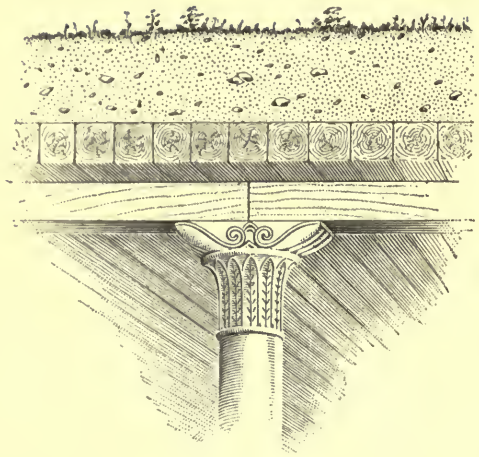


FIG. 6.

been beautified in many cases by varied vegetation, such as flowers, etc.

The earlier Egyptians and successive peoples constructed their roofs of flat slabs of stone, supported on stone lintels or beams resting on columns (see Fig. 7), and these, in turn, were succeeded by tiles on boards or vaulted stone roofs.

5. Tile Roofs.—The history of tiles as a roof covering is too extended to completely review; tiles, however, deserve

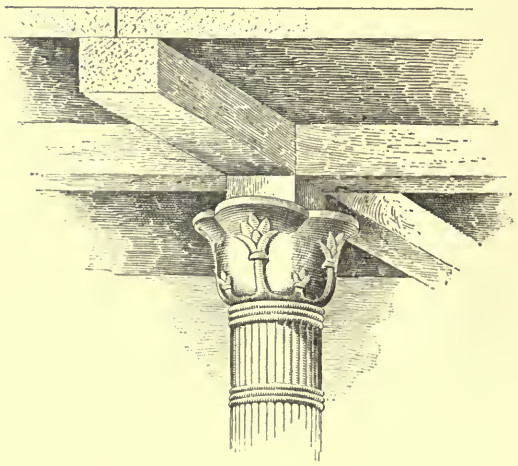


FIG. 7.

special mention, because they are the most desirable and the most serviceable materials used for roofing.

The earliest mention of tiles occurs perhaps in the Book

of Kings, in the description of Solomon's Temple. They have been used in China from a period of such remote antiquity as 2,000 years B. C. Whether the manufacture of roofing tiles was carried from China to India and Persia, and thence to Egypt, Phœnicia, and Assyria, or whether it was a native and spontaneous product of these peoples, who were the first to develop the artistic resources of the human intellect, is a disputed question. It was from these countries, undoubtedly, that the art found its way through Greece into Europe, where it was soon carried to great perfection. Tiles were used by the Grecians, Romans, Venetians, and most nations of southern Europe. The history of tiles, during the intervening time, from the Romans to the Mussulmans, Saracens, and Moors, is not known, but its revival is due to the last named. From 732 to 1492, Spain was famous for its potteries, as were also India and Asia Minor. The tiles most used were flat tiles turned up at the edges, with a row of inverted semicylindrical ones over the joints.

In the Middle Ages, tiles were the principal covering, though stone slabs were much used and laid in the same manner as shingles, supported on barrel-vaulted roofs.

6. In the following outline, the types of roofing tiles are illustrated in a general way, and mention is made of those by whom they were originally used.

Tiles are supposed to have been first brought to America by the German settlers in Pennsylvania, and were of the flat variety. The pan tile was brought by the Dutch, who settled on the Delaware River, New Jersey; and the Spanish tile, by the old Jesuits to California.

For the *normal* (Asiatic), see Fig. 8. Those marked (*a*) were used in the Orient, Ancient Greece, and Italy; those marked (*b*), in China and India; those marked (*c*), in the Orient, in Asia, and the Mediterranean countries, south of latitude 44°; those marked (*d*), in Greece and Italy, ancient and modern. For the *pan* (Belgic), see Fig. 9. Those marked (*e*) were used in England and Scandinavia; those marked

(*f*), in Belgium, Holland, Scandinavia, Japan, and Java; those marked (*g*), in various modern countries. The *flat*

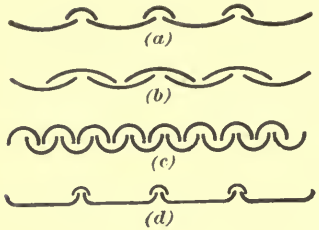


FIG. 8.

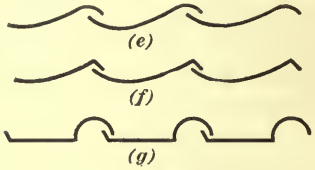


FIG. 9.

(Germanic) were used in Germany, Austria, Hungary, Poland, Switzerland, France, and England.

7. Metal Roofs.—Metal roofs may rightly be termed modern roofs. Lead was the first of these to be introduced; copper, zinc, and galvanized iron followed. Lead and copper were used in medieval times for covering roofs, but it was not until about 1760 that they came to be used as a general covering for large buildings.

Wood shingles and **slate** were known at an early period, and were used in the form of slabs having considerable weight. Edward II gave an order, in 1314 A. D., to replace the shingle roofs of certain government buildings with slate, thus showing that, even at that time, both were extensively used, though it is commonly supposed that wooden shingles are of a very much later date.

Tin, the most extensively used roof covering in the United States, was originally a North German product, and was made there as early as 1600; it next was made in Bohemia, 1620; at Pontypool, England, in 1670; and at Mausvaux, France, in 1714; but not until recently, in the United States. England produces at the present time 90 per cent. of all that is manufactured.

8. In the following pages, the different styles, methods, and materials used for roofing, as well as the application of each to the particular form or style of roof to which it is best adapted, will be discussed in the order of their importance and historical development.

GENERAL TERMS AND DEFINITIONS.

VARIETIES OF ROOFS.

9. The names of different roofs are determined: (1) by their *style;* (2) by their *outline;* and (3) by their *angle of inclination*, or *pitch*.

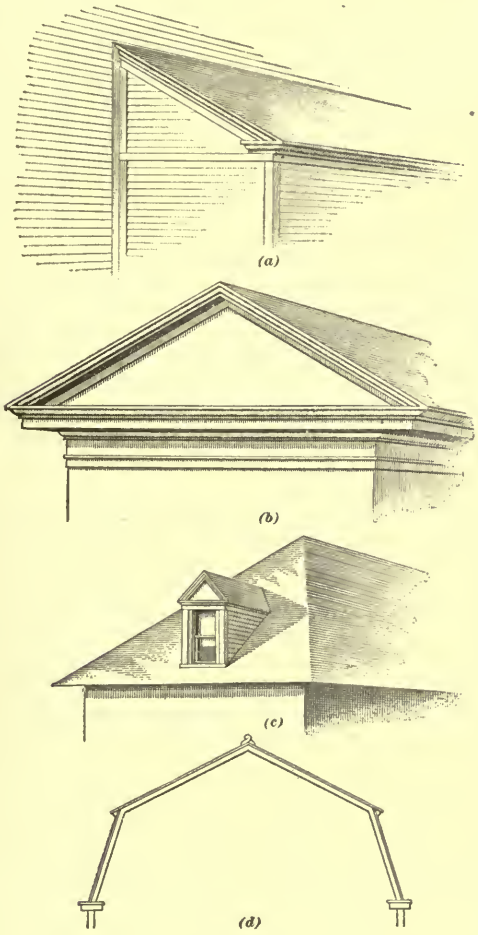


FIG. 10.

In Fig. 10, at (*a*), is shown a *pent*, *shed*, or *lean-to* roof; at

(*b*), a *gable* roof; at (*c*), a *hip* roof; and at (*d*), a *curb*, or *gambrel* roof.

In Fig. 11, at (*a*), is shown a *Mansard* roof with deck, or flat, top; at (*b*), an *ogee* roof; at (*c*), a *semicircular*, or *barrel*, roof; and at (*d*), a *hip-and-valley* roof.

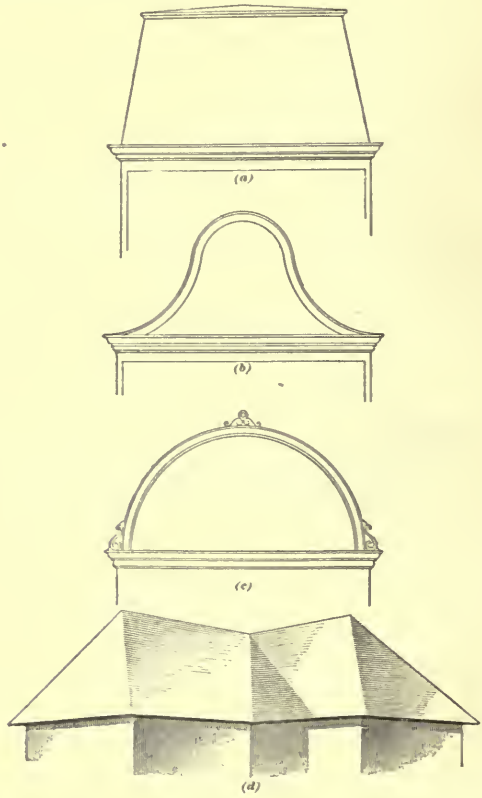


FIG. 11.

In Fig. 12, at (*a*), is shown a *dormer-window*, with cheeks, or flanks; at (*b*), an *eyebrow* window; at (*c*), a *squint* with cheeks, or flanks; and at (*d*), a *louvre ventilator*.

The pitches are regulated by a recognized standard of the style to which they belong. Thus, at (*a*), Fig. 13, is seen the pitch, generally found in Grecian design; i. e., inclined from

12° to 16°; at (*b*), the inclination is from 23° to 24°, which was the rule in Roman design; at (*c*), is shown the Gothic, or equilateral, pitch; and at (*d*), the Elizabethan, or knife-edge, pitch.

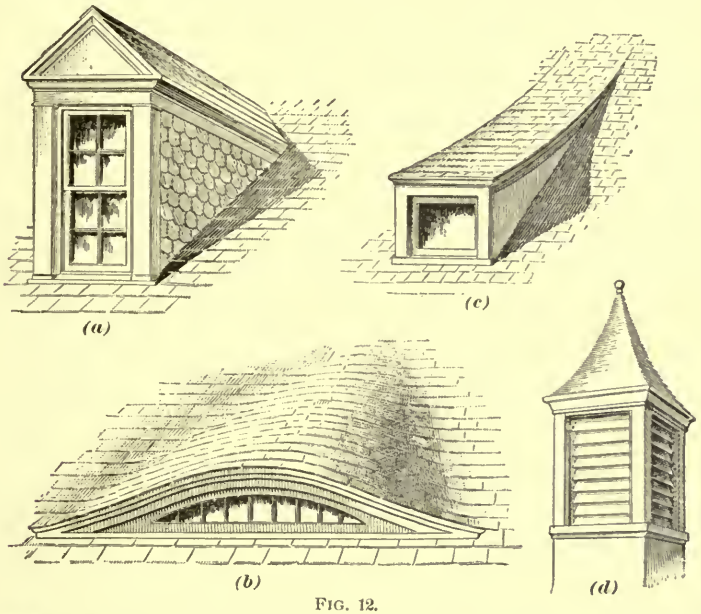


FIG. 12.

10. A **dome,** properly speaking, is a spherical form of roof; the term, however, is now applied to various forms having a circular base; thus, in Fig. 14, at (*a*), is a *surmounted* dome; at (*b*), a *semicircular* dome; at (*c*), an *ellipsoidal* dome; at (*d*), a *segmental* dome; and at (*e*), a *bell* dome. There are many other varieties, known as Turkish, Saracenic, Russian, etc.

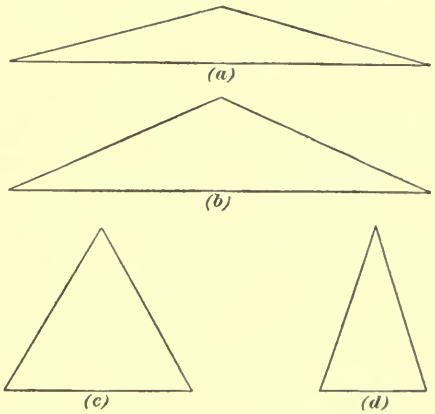


FIG. 13.

PARTS OF A ROOF.

11. The following terms are applied to express the different elements or details which exist in nearly all roofs:

Span is the distance between the supports.

Rise is the vertical distance between the ends of a slope.

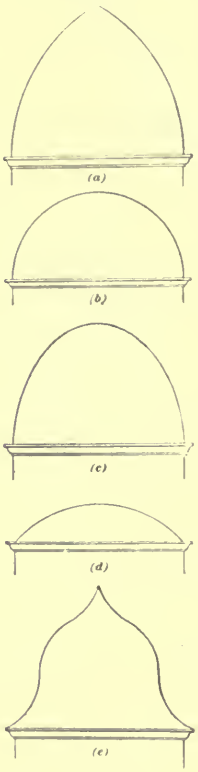


FIG. 14.

Run is the horizontal distance between the ends of a slope.

Pitch is the slope of the rafters as determined by both the rise and run.

The **eaves** are the lower part of the roof projecting over the walls.

A **gable** is that portion of a wall extending above the eaves; it is generally built to the shape of the roof abutting or covering it.

Hips are the salient angles formed by the intersection of the roof slopes.

Valleys are the re-entrant angles formed by the intersections of the slopes. A **close** valley is that in which the material used in covering the roof is mitered and flashed at each course, no metal being exposed. **Open** valleys are formed by sheets of metal laid with a portion of their sides under the material used in covering the roof, and with the center part, or valley gutter, left exposed for a width of 4 or 5 inches on each slope.

The **ridge** is the line formed by the meeting of the slopes of the roof at its summit, or apex.

Saddles are small inverted **V**-shaped pieces of roof, placed at the backs of chimneys or other portions of a building, protruding through and above the roof. They serve the double purpose of shedding the water and preventing snow and ice from accumulating.

A **cant** is an angular-shaped piece of roof, used on flat-pitched roofs with parapet walls and placed at the lower end of the roof, commencing at a point at the leader head, and gradually

running out on the roof, until, at the opposite end, it is 4 or 5 feet wide and extends up on the wall about a foot. It is also used back of bulkheads, etc. for the same purposes as the saddle.

A **curb,** or **combing,** is a support for a skylight, or scuttle, and surrounds the opening cut in the roof.

A **bulkhead** is formed by a partition built around the openings cut into the roof for elevators, stairways, dumb waiters, and air-shafts. It is also occasionally applied to the vertical or sloped backing in the rear of the main cornice.

A **tilting strip,** or **fillet,** is a triangular strip of wood used to raise the flashing, shingles, slate, tile, etc. at the eaves, gable ends, around chimneys, skylights, bulkheads, and ventilators, or against parapet and gable walls, to prevent the accumulation of dust, water, or snow.

DESIGN AND CONSTRUCTION OF ROOFS.

GENERAL CONSIDERATIONS.

12. In planning a roof, the first thought must be given to the pitch, which depends upon the climate, against which it is to act as a protection; the second consideration is the devices of construction to aid the free flow of water from the whole external surface when covered; and the third is the determination of the materials best suited to both the pitch and climate.

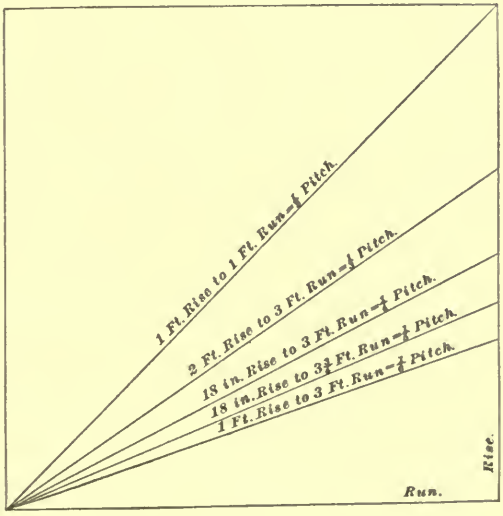

1 Ft. Rise to 1 Ft. Run = ½ Pitch.
2 Ft. Rise to 3 Ft. Run = ⅓ Pitch.
18 in. Rise to 3 Ft. Run = ¼ Pitch.
18 in. Rise to 3½ Ft. Run = ⅛ Pitch.
1 Ft. Rise to 3 Ft. Run = ⅓ Pitch.
Rise.
Run.

FIG. 15.

13. Fig. 15 is a diagram of comparative pitches, from $\frac{1}{6}$ to $\frac{1}{2}$ pitch, and the following table gives a list of roof materials and the least pitch permissible with each:

TABLE 1.

Material.	Pitch. Inches to the Foot.
Asphalt and composition	$\frac{1}{2}$
Tin	$\frac{3}{8}$
Zinc	$\frac{3}{8}$
Corrugated iron	$\frac{1}{4}$
Sheet iron	$\frac{1}{2}$
Copper	$\frac{1}{2}$
Lead	$\frac{3}{8}$
Thatch	6
Shingles	4
Slate	4
Tiles, terra cotta or copper	4

14. Although there are no invariable rules governing pitches, it has been the custom to construct slopes suitable to different localities, and to use the materials which are best adapted to meet the climatic changes.

In hot countries, the lack of rain makes it unnecessary to give the roof more pitch than enough to shed the water; but the roof must be well constructed and tight, for when the rain falls in hot regions it does so in great volume.

Rapid evaporation is a great help in preserving the roof, for the moment the rain ceases the roof is dried, and the conditions tending towards corrosion or decay of the materials are soon removed.

In cold climates, where the air holds the moisture, and the rain and snow are driven by high winds, the pitch must be steep, to prevent the loosening of the shingles, slate, or tile by the wind, and to cause snow and moisture to be quickly shed from the roof.

In temperate climates, the pitch may be varied as the locality approaches either the warm or the cold zones.

In very wet, damp, or cold situations, the roof is given a pitch of from 40° to 60°; in dry climates, where the roof is quickly cleaned of water, a moderate pitch of from 20° to 30°; and in hot climates, only sufficient to shed the water.

This must, of course, be varied with the material used. Thus, shingles, slate, or tiles could not be used in a hot climate, unless the pitch were sufficient to keep the water from driving under them, or overflowing their edges during a rainfall. Neither could lead be used on a steep-pitched roof, as it would crawl off by expansion.

15. The roof should be carefully prepared for the covering; and all pockets, where ice, snow, or water can accumulate, must be studiously avoided in the construction.

On steep roofs, the backs of chimneys, or other vertical walls cutting the roof plane, must be fitted with a saddle or cant board.

All angles made by corners or flashings against walls should be avoided, and a tilt fillet or cant board must be used, to allow the flashing to take an easy bend. In slate, shingle, and tile roofs, this observance will assist the passage of water and snow and prevent its accumulation. On metal roofs, the sand, dust, or other refuse blown thereon will not so readily lodge. Where such accumulations do lodge on the roof, they keep it damp, rotting and corroding the most vulnerable parts.

16. The boarding should run one way, so that the shrinkage may be uniform and not pull and tear the joints of the roofing material. With metal roofs, it is best to have the boards laid from the eaves to the ridge, as this, in case the boards warp, brings the ridges thus raised in the roof in line with the current or pitches. This is not always practicable, but in any case it is possible to lay the boards diagonally. The nails driven from the surface of the roof must be countersunk at least $\frac{1}{4}$ of an inch below

the top of the boards, to prevent corrosion and wear of the covering.

17. Double gables, or dormers, in which the roofs form an ⩚ should not be erected, it being impossible to keep them clear of snow in winter; for the same reason decks should not be used, unless unavoidable.

THATCHING.

18. Thatching on a house is an admirable covering for securing warmth in winter and coolness in summer, but, being subject to injury from birds and a great risk from fire, is very seldom used. A good thatch roof has been known, when well put on and composed of sound straw, to last from 10 to 14 years; while in respect to its being the most picturesque form of covering for cottages, arbors, and like buildings, there can be no room for question.

19. The roof is prepared to receive the thatching by nailing to the rafters, lath, or light purlins, at 8-inch centers (see *a*, Fig. 16), on which the straw is laid. Like slating or shingling, the thatching is commenced at the eaves by laying on bundles, about 3 or 4 inches in thickness, and securing them to the laths, using a thatcher's needle and rope yarn. The yarn is tied around the purlins as at *a*, Fig. 17, or hung with thatching hooks, which are tied to the head of each bundle and hooked over the purlins. Starting at the end

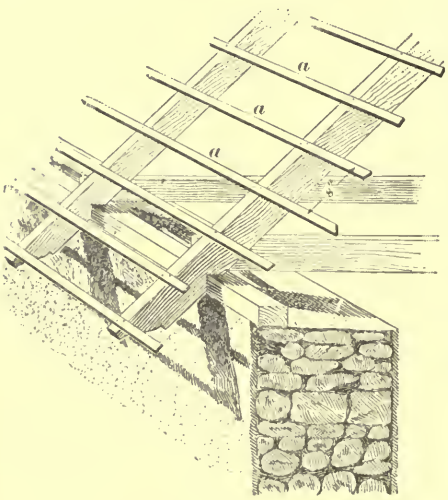


FIG. 16.

wall, or at the gables, full-width bundles are laid until a row reaches the ridge, the thickness of the completed row being from 12 to 15 inches.

After two or three rows have been put on, they are interlaced with *withes*, or *reeds* (see *b*, Fig. 17), the ends of the withes being bound together and nailed to the purlins; the withes may also be tied to the purlins with the yarn.

The rods *c* are run through the thatch when 8 or 10 feet have been laid; they are spaced about 2 feet apart, and are secured by looping a withe over the rods and nailing the ends to the rafter.

Where the thatch comes against the gable wall, the joint must be well filled with lime mortar. After allowing this to thoroughly settle, it is pointed with cement mortar, carried well up against the wall. Similar pointing should be used about chimneys or other openings, or a canvas flashing may be nailed to the walls with a wood strip at the top, the flap being turned out on the thatch and the whole thoroughly tarred.

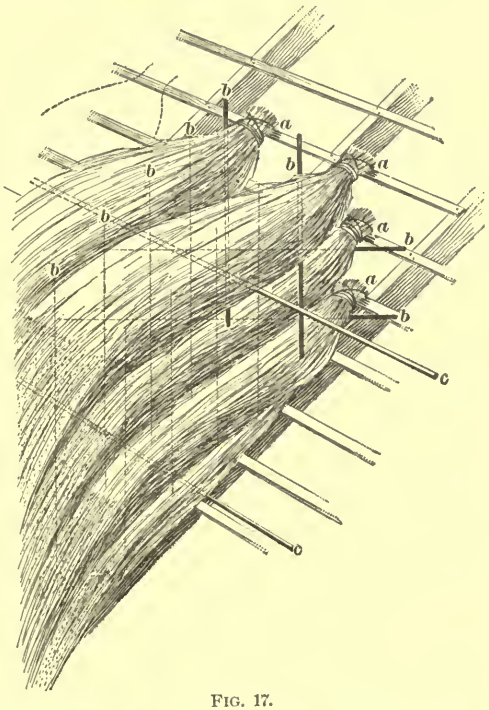


Fig. 17.

The ridge may be formed of thin bundles of straw, laid with the middle on the ridge and afterwards withed down to the roof [see (*a*), Fig. 18]; or

the straw ends of the upper layer may be turned up and withed together and surmounted by a terra-cotta ridge cresting set in cement, as shown at (*b*), Fig. 18.

The eaves may be raked out until the edge is very fine, thus forming a round, easy shed for the water [see (*a*), Fig. 19], or cut off on the under side, as shown at (*b*), Fig. 19. As each course is laid, the lap ends should be raked out, to maintain as even and continuous a surface in the finish as possible.

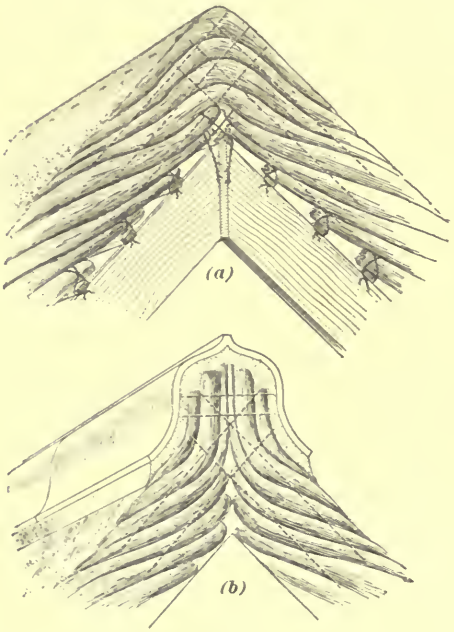


FIG. 18.

20. The thatcher requires the following tools: a common stable fork, to toss the straw together before it is made into bundles; a thatcher's fork, to carry straw up to the roof; a thatcher's rake, to comb down the straw straight and smooth; a knife, to point the withes; a half glove of leather, to protect the hand when drawing or pushing in the smaller withes; a long, flat needle; a pair of leather gaiters, to come above the knees, used when kneeling on the rafters.

The materials required are: good straw of any kind, or straw reeds, wheat straw being the best; also rope, nails, withes, and rods.

To complete a square of roof, the materials necessary are: two-thirds of a load of straw, laid on about 12 to 14 inches thick; a bundle of oak laths, $1\frac{1}{4}$ inches wide and from $\frac{1}{2}$ to $\frac{3}{4}$

inches thick, nailed to the rafters, as in Fig. 17; 75 withes;

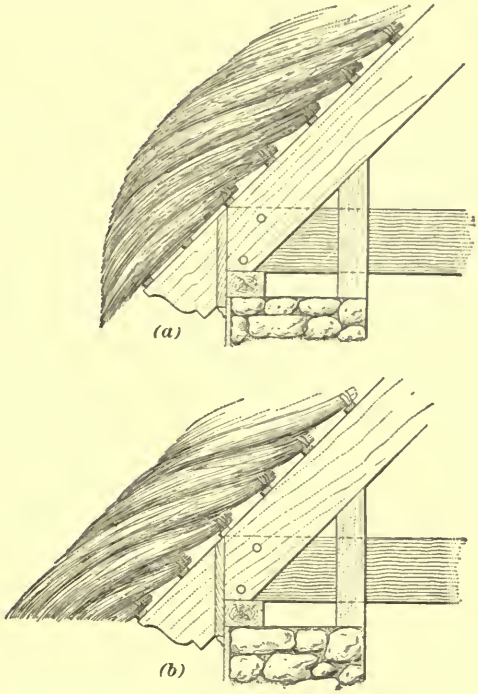


FIG. 19.

1½ pounds of rope yarn, or, in its place, Manila rope; 35 rods; and 250 nails.

ASPHALT ROOFING.

21. **Asphalt,** or solid bitumen, is found in several countries. Asphalt, combined with calcareous earth, that is, earth containing lime, forms a compact, semielastic solid, not liable to injury from the strongest influences of frost or thaw, impervious to water, and unaffected by acids.

22. There are three methods of laying asphalt:

The *first* and most durable method consists in laying felt entirely free from saturation with asphalt, then applying a coat of asphalt in solution, and finishing with a covering of gravel.

The *second* method consists in laying sheets of felt saturated with asphalt, finishing with sand.

The *third* is similar to the first, except that the finishing is done with a coating of Portland cement.

23. The application is very much like that in use in other composition roofing, except that the first and third methods call for copper or lead flashings. Two thicknesses of the composite roofing felt is stretched from the eaves to the ridge, the Manila side of the felt being placed downwards, the felt being secured with nails about 2½ feet apart. The entire surface should then receive a coating of natural asphalt cement.

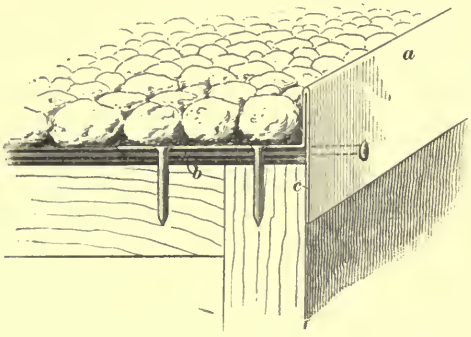


FIG. 20.

Another thickness of the felt should be laid in the cement, securing it at the upper edge by nails 4 feet apart, lapping each successive sheet about 1 inch over that preceding it. Over the entire surface of the felt thus laid, there should be spread an even and continuous coating of the cement, and this coating should immediately be covered with an adequate body of well screened gravel.

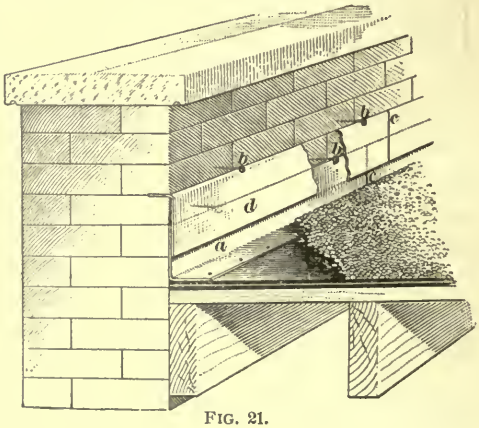


FIG. 21.

24. The **flashing** for this roof should preferably be of copper, as

should also the eaves stops and nails. Flashings of zinc, galvanized iron, or tin may, however, be used as fairly satisfactory substitutes for copper.

The **eaves stops** (see *a*, Fig. 20) should extend 2 inches on the roof as shown at *b*; they are laid over the felt and should extend downwards over the eaves *c* not less than ½ inch below the upper surface of the roof boards.

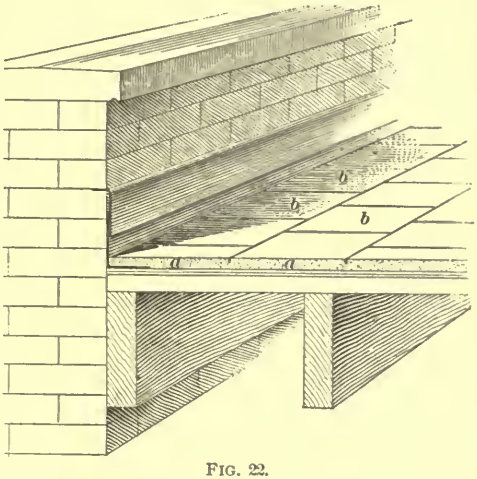


FIG. 22.

The *wall* flashings *a*, Fig. 21, extend at least 2 inches under the felt on the roof. They should be well nailed, and should be covered with cement when the gravel is applied; they should project upwards against the wall at least 5 inches and be secured with flashing hooks, and should have the vertical joints *c* well locked and soldered.

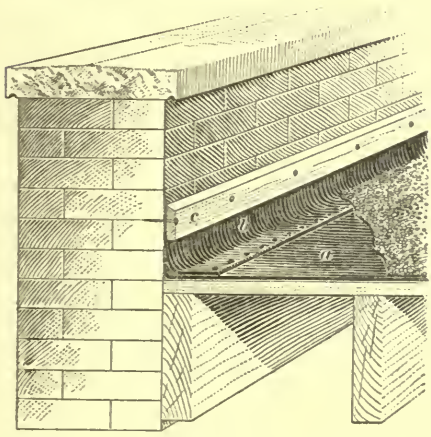


FIG. 23.

The flashing should be covered with a *counterflashing d*, Fig. 21, which reaches within 2 inches of the roof, and is turned in to the wall at least 1 inch and secured by wall hooks or plugging. The joint should be pointed with elastic cement.

This roofing may be covered with a layer of hydraulic

cement, as shown at *a*, Fig. 22, $1\frac{1}{2}$ inches thick, divided into small sections *b*, *b* suggestive of stone or tile.

In the second method (see Fig. 23), the flashings are of the same material as the roof. In this method the felt *a* is laid close in to the angles against the walls, and is extended 2 inches upwards. Over this, in the angles, is laid a strip *b* 8 inches wide, with half its width against the walls and half on the roof. The upper edge is fastened with a wooden strip *c*, nailed to the walls and pointed with cement; the felt is pressed in to the angles of the wall and cemented to the roof with liquid coating. In securing the laps of the prepared felt, the nails should be spaced about 1 inch apart.

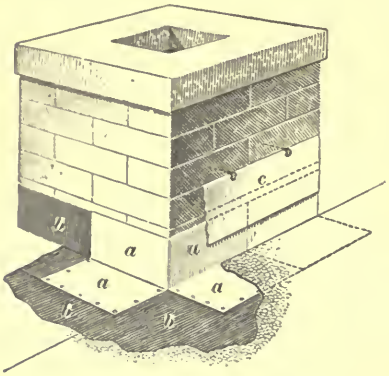


FIG. 24.

The outside angles of walls and chimneys should be flashed, as shown in Fig. 24. A strip of felt *a* 8 inches wide is folded and cut as shown. It is bent around the angle, and is nailed and cemented, with the liquid coating, over the under roofing *b*, after which it is counterflashed as shown at *c*.

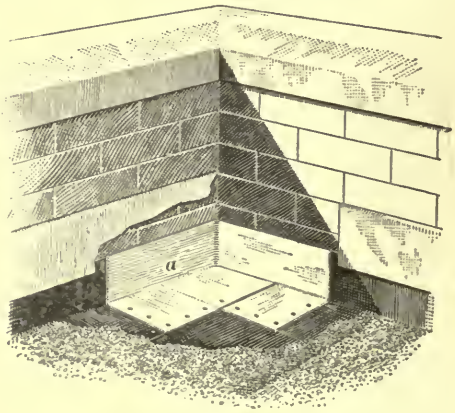


FIG. 25.

The inside angles of walls are flashed, as shown in Fig. 25, the strip of felt *a* being of the same dimensions and similar to that used for outside angles; the process of applying is the same.

The **ridge** is capped with a 16-inch strip of felt, lapping on the roof each side of the ridge, well cemented and securely nailed at the edges and joints. The best temperature to apply this roofing in is one of 35° F. When it is colder than this, the material should be kept in a warm room before using, and taken out only as required.

The quantity of material required to lay and cover a square of this roofing is: 1 roll of 2 or 3 ply natural asphalt roofing; 2 gallons of liquid coating; 1 pound of nails; and 1 pound of tin caps.

ASBESTOS ROOFING.

25. **Asbestos** is a white, gray, or green-gray fibrous variety of amphibole, usually one containing but little aluminum, trenolite, or actinolite; also, improperly, a fibrous serpentine or chrydolite. The fibers are sometimes very long, easily separable, and flax like, sometimes compact and capable of a high polish. It is very soft when reduced to powder. It is incombustible, and from white, green, and gray, turns red and black. Asbestos is mined in Canada, Vermont, Virginia, South Carolina, and Staten Island, N. Y.

26. Before the application of asbestos, the roof surface should be cleaned of all refuse. Care should also be taken that the joints of the boards are planed to a level surface and then thoroughly swept.

Unroll the roofing as shown in Fig. 26, taking care that the material passes over and not under the roll. Cut enough off the roll to cover the length required. Commencing at the eaves, lay the sheets in succession parallel to the eaves. The lap for steep roofs should be 1½ inches, and for flat roofs, 2 or more inches. Where short lengths are used, see that the vertical joints do not come in line with each other;

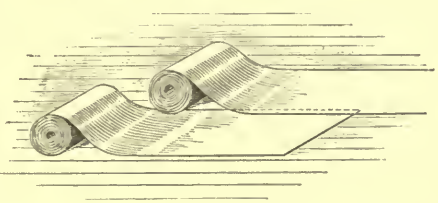


FIG. 26.

and on steep roofs, where the roofing is vertical, or from ridge to eaves, place a continuous strip next to the short lengths. All edges and laps are cemented before being nailed down, the nails being spaced 1 inch apart. When the roofing has been nailed, cement a second time, thoroughly covering the joints and laps, concealing all nail heads and filling up the edges as much as possible. Next apply a coating to the entire surface of the roof, and when thoroughly dry, apply a second coating, finishing, while fresh, with an even covering of fine ground asbestos powder.

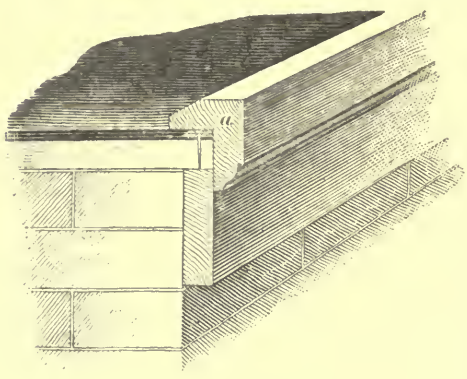


FIG. 27.

Where there are no gable walls, the roofing is thoroughly cemented at the edge of the roof, with a coating mixed and thickened with hydraulic cement. It should, also, be nailed down close and tight and then covered with a wooden cap molding *a*, as shown in Fig. 27.

27. Where there are parapet walls, chimneys, bulkheads, etc., the roofing should run to the angle only. See Fig. 28. When the roofing has been nailed in place, the angle formed by the roof and walls should be thoroughly cemented. While this coating of cement *b* is wet, apply a separate flashing *c*, as shown; this flashing to be 8 inches wide, 4 inches on the roof and 4 inches up against the walls, nailed and also cemented.

Where a metal counterflashing is used, secure the upper edge of the flashing *c*, just mentioned, with a wooden strip *d*, well nailed to the walls, finishing the top with a good coating of cement *e*. By using a wide strip of wood, and keeping the top of it flush with a joint *f* in the brickwork,

the mortar can be raked out and the coating of cement made to enter the joint, thus rendering it more secure and water-tight.

Apply tin, copper, or zinc, where used for counterflashings, in the same manner as in other roofs. In fitting around the corners of chimneys, etc., take a piece of roofing 8 inches square, and from the middle point of either side, cut it half across; bend this on the angles as required and cement well. This pattern will suit an outside or an inside angle. See Figs. 24 and 25. Where the roofing connects with tin, or other metal portion of the building projecting through the roof, the edges should be carefully secured by nailing and cementing.

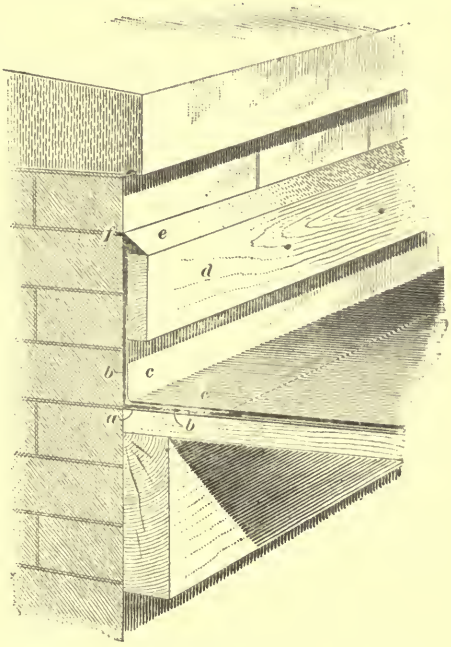


FIG. 23.

28. At the leader outlets (see Fig. 29), turn the leader sleeve over the gutter; cut a piece of roofing felt *a* with a hole in it the size of the outlet; place this over the sleeve's edge; then cement and nail in place. If the gutters are to be lined with the roofing felt, use a separate strip *b* in the trough, and put it in place before applying the material *c* on the roof proper. Nail and cement all the edges and laps, and give an extra coat of cement. Avoid forming sharp angles in the roofing felt, and take care not to injure the material while applying it to the roof.

29. See that all laps are made with the current, or pitch, of the roof. Large roofs should have a pitch of not less than 1 inch to the foot. This roofing should not be applied

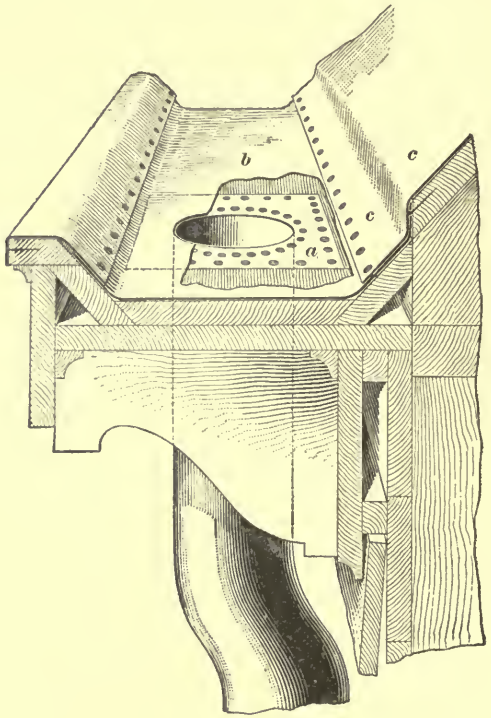


FIG. 29.

when the temperature is below 40°. With this method, it requires to cover a square: $\frac{1}{2}$ roll of roofing material, $1\frac{1}{2}$ gallons of coating, and $1\frac{1}{2}$ pounds of nails.

SHINGLE ROOFING.

WOOD SHINGLES.

30. **Shingles** are made by sawing or splitting chestnut, hemlock, cedar, white pine, or cypress.

Chestnut shingles are likely to curl in dry weather, and

when damp they swell and bulge; this continued movement gradually draws the nails and cracks the shingle.

Hemlock shingles are more serviceable than is generally supposed, and in dry localities last a long time; but in a moist atmosphere they rot quickly.

Red-cedar shingles last very well, and are on this account largely used. Because of the general straightness of the grain, red-cedar shingles are not roughened so much under the sun as other kinds, and, therefore, give a better weather surface.

White-pine shingles are commonly used, because, while offering most advantages under general requirements, they last longer than any but cypress or white-cedar, and do not curl and split so readily as the foregoing kinds. Their chief disadvantage is in the sawing, as the fiber roughens quite freely.

Cypress and *white-cedar* shingles are the least used, and, at the same time, the best that can be had. The wood saws fully as well as the red cedar, and will not curl or split, except under excessively severe conditions; as regards enduring qualities, these shingles are far superior to any other shingles known.

31. Sizes and Terms.—The ordinary lengths of shingles are from 16 to 18 inches, or 24 to 27 inches, and the widths, from 3 to 7 or 10 inches. A bundle contains about 250 shingles. Thick shingles measure about $\frac{9}{16}$ inch, and thin ones about $\frac{3}{8}$ inch at the butt. Shingles are wedge shaped and $\frac{1}{16}$ inch thick at the upper end.

Dimension shingles are always cut to a uniform size or width, and are preferable in laying patterns; they are 4, 5, or 6 inches in width, and are usually dressed.

The term *No. 1* signifies that the entire shingle is of a clear, sound, serviceable wood, free from all knots, sap, etc.

Shaved shingles are split and shaved with the draw knife.

Clear butts indicate that the shingles contained in the bundle have a clear butt, or enough clear surface for the exposure to the weather.

Fancy butts, or *pattern butts*, are shingles having the butts, or ends, sawed to a geometric or other form, such as saw tooth, round, hexagonal, etc. These shingles are usually dressed.

Shingle lath, on which the shingles are laid, usually runs from $1\frac{1}{4} \times 2$ inches to $1\frac{1}{4} \times 3$ inches.

Valley, *hip*, and *ridge boards* are of either 1 inch or $1\frac{1}{4}$ inches in thickness, as required.

LAYING SHINGLES.

32. The methods of laying shingles generally in use are: (1), on shingle lath; (2), on boarding without paper or felt; and (3), on matched boarding and lath with felt.

The *first* method is, no doubt, the best, though generally used only on cheap buildings. In more expensive houses, the requirements usually call for a matched-board roof, which prevents the free passage of air, and causes the shingles to rot.

33. To lay shingles according to the first method, commence at the eaves and lay from one to three hemlock boards 10 inches wide. The advantage of using more than one board is, that, if it becomes necessary to walk on the eaves of the roof to make repairs, the shingles will not be so readily broken. In the valleys formed by the main roof and dormers, where not very long, one board, however, on each side is sufficient. These boards also act as a stop to the wind, and, to a great extent, prevent the rain from being blown over the flashing. The same remark applies to hips and ridges.

The starting course of the shingles should be doubled at the eaves, and the ends should overlap the gutter about $1\frac{1}{2}$ inches.

Each shingle is secured with 2 fourpenny nails, at a distance of about 2 inches above the upper line of the exposure. The amount of exposure or gauge is measured back from the butt ends of the shingles, and a mark is struck with a chalk line, to which mark the butts of the next course of shingles are laid. The heads of the nails are in this manner protected by the laps, and the shingles are further secured

by the nails of each succeeding course passing through the heads of the previous course. If the gutter is built on the surface of the roof, as shown in Fig. 32, the butts of the shingles must be placed well up above the overflow line.

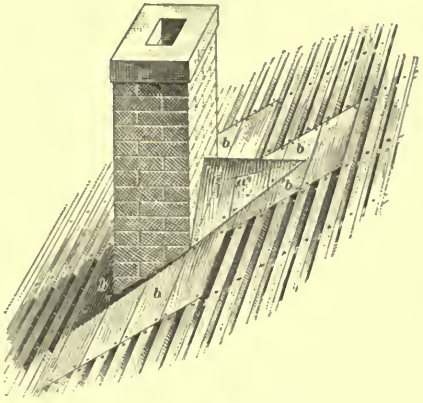


FIG. 30.

34. Around all chimneys, ventilators, skylights, etc., board the roof to the first rafter on each side; and at the back of all chimneys, build in a saddle, as shown

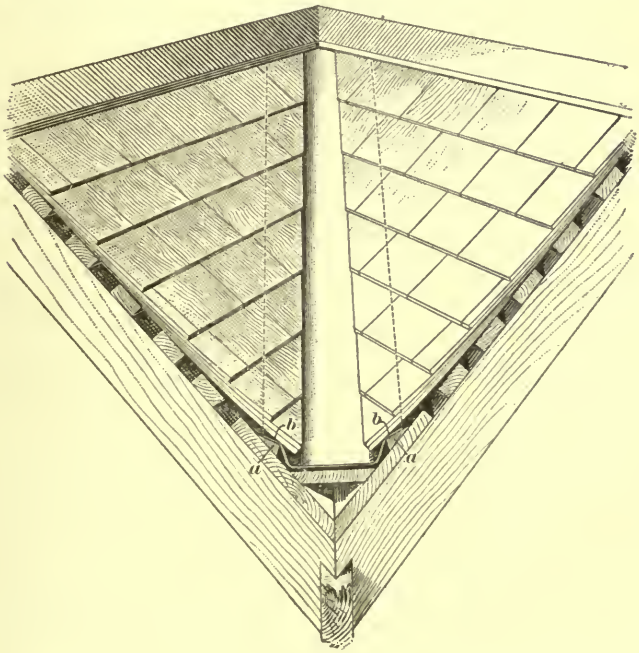


FIG. 31.

at *a*, Fig. 30, and nail the boards *b* at each side and at the front.

Along the valleys should be placed tilting fillets *a*, Fig. 31, over which the flashing is formed. Similar tilting fillets should be placed along the upper edge of the gutter just above the overflow.

Gutter linings may with advantage extend several inches up under the shingles. See *b*, Fig. 32. The valley lining also extends under the shingles 3 or 4 inches, as shown at *b*, Fig. 31;

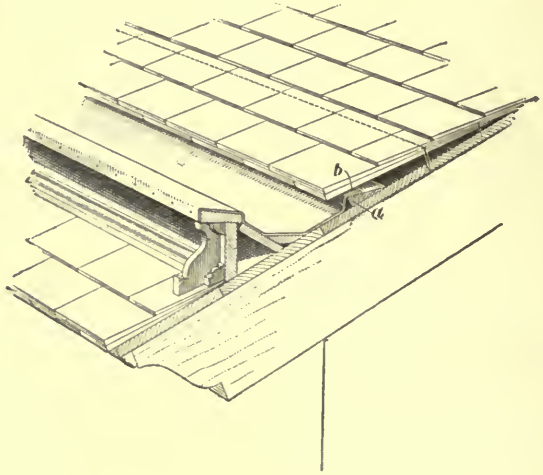


FIG. 32.

likewise, the chimney flashing extends 3 or 4 inches at the back and sides of the chimney, and 5 or 6 inches at the front.

35. Valleys.—In finishing against open valleys, care should be taken to cut the shingles parallel to the line of the tilting fillet, or the result will be a wavy line.

In constructing *close* valleys, the shingles are interwoven with metal sheets (see Fig. 33), and are mitered in the angle. The shape of these sheet flashings will vary with the pitch of the roof, if it is desired to make the lower edges of the sheets parallel with the butts; but this is not necessary, as square sheets will serve the same purpose, provided they are properly lapped.

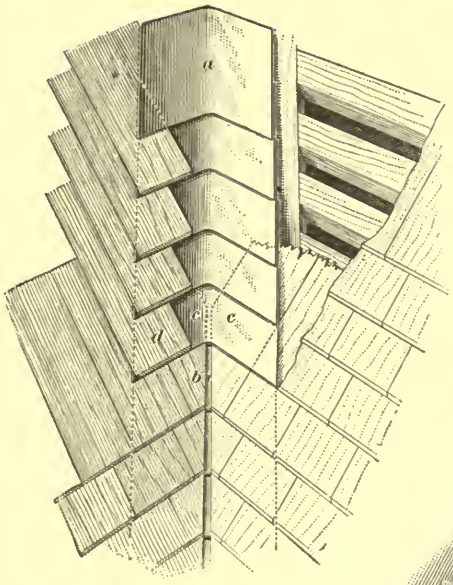


FIG. 33.

The general manner of constructing this valley is as follows: A row of shingles should be laid each side of the valley, a clear space of $\frac{1}{2}$ inch being kept between the miter edges as shown at *b*, to allow for expansion. The gauge should then be measured, and the flashing set, as shown at *c*, to the line so obtained; the next course of shingles, as shown at *d*, covers the metal entirely, and each ascending flashing will be covered in like manner. This gives a tight valley and is used more on account of appearance than durability; for the snow and rain keep the shingles damp, consequently causing them to rot before the rest of the roof.

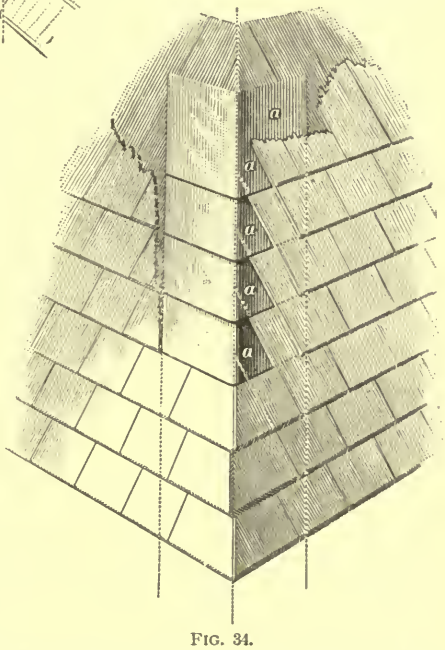


FIG. 34.

36. This method, applied to the hips of roofs, is shown in Fig. 34, *a* being the flashing laid in with

the shingles. While not prolonging the life of the shingles, this no doubt makes the most weather-proof hip except a metal roll. The roll, however, never looks well, and on that account should be avoided.

37. The method known as the **Boston hip** is very effective and neat, and under ordinary conditions, especially on a very steep roof, is sufficiently weather-tight for all purposes.

Shingles of a uniform width of, say, 5 inches, should be selected. A chalk line is snapped on either side of the hip, about 4½ inches from its center and parallel to it. See *a*, Fig. 35.

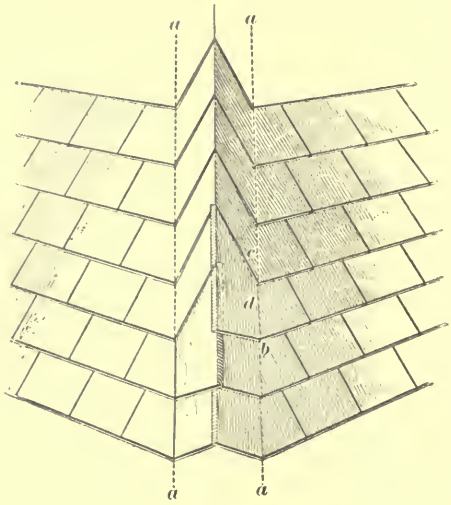


FIG. 35.

The slope shingles should be carried up to this line, stepping back to allow the hips to be laid last. Lay a shingle on the roof with its edge at, and parallel to, the hip line, and the lower corner of its butt just touching the butt of the shingle below it, as shown at *b*. Across it, and at right angles to the eaves, draw a line for the vertical side cut, as at *c*. Slightly taper the side *d* to heighten the effect of a hip roll, and to allow the next hip shingle above to slightly project over and cover the end of the vertical side cut. Fit the slope shingle to the side or vertical cut, and nail the hip shingle in place. Now repeat this from the other side, laying the edge of the shingle flush with the upper and outside edge of the first shingle, obtaining the side and butt cuts in the same manner as before; the third shingle is laid on the same side as the first, with the hip edge flush with the outside edge of the second, and the fourth from the side of the

second; continue thus, laying alternately, until the hip is completed.

One of the chief advantages of this method is, that the grain of the wood runs with the hip, and the tendency to curl is taken away from the line of the hip to the side of the shingle.

The appearance of the roof may be improved, and the drip over the gables may be stopped, by putting a tilting fillet up the rake, running the shingles up on it as at *a*, Fig. 36, and cutting the ends of the shingles at an angle of 45° to the side joint, as shown at *b*.

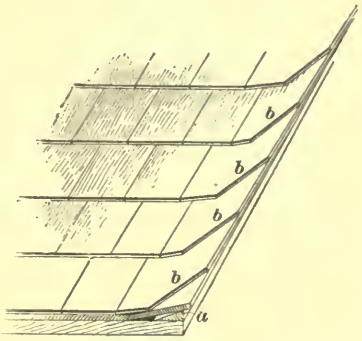


FIG. 36.

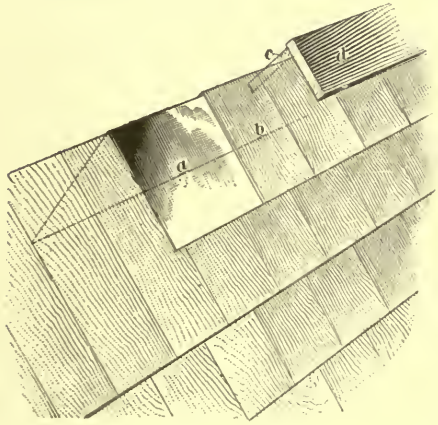


FIG. 37.

38. There are three methods of finishing the ridge of the roof. The *first* consists of laying over the last row of shingles but one, a metal flashing, as at *a*, Fig. 37, which extends on each side of the ridge to the depth of the last row, after which the last row of shingles may be laid and the ridge capped with a ridge saddle of white pine $1\frac{1}{4}$ inches thick. The first side *c* is put on flush with the ridge and opposite side of the roof, and the finished piece is put on with a lap of about $\frac{1}{2}$ or $\frac{3}{4}$ inch, as shown at *d*.

The *second* method [see (*a*) Fig. 38] consists of the two ridge pieces *a*, *a*, one being the thickness of the board wider

than the other, laid over two pieces just the thickness of the shingles, which are first nailed to the roof-boards, and against which the shingles abut. The top of the ridge piece is capped with a wooden roll *b*, Fig. 38. No metal flashing is required, as the roll effectually covers the joint.

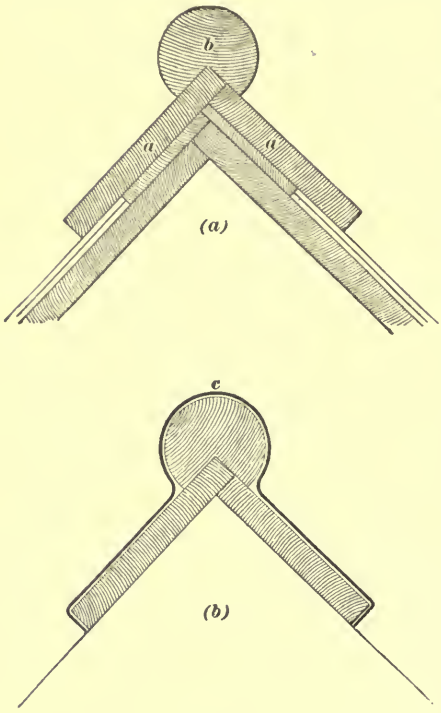


FIG. 38.

The *third* method [see (*b*), Fig. 38] is similar to the second, except that the wood roll is covered with a galvanized-iron or copper roll and wings pushed over it. Galvanized nails are driven into the roll, near the wings, to keep it in place; lead is also used for the same purpose.

39. The *second* method of laying shingles is that of laying them on boards, which cover the entire surface of the roof. The boards should not be set close together, as they would then prevent the passage of air, stop ventilation, and cause the shingles to rot. This process of rotting arises from the warm air of the rooms below condensing when it comes in contact with the roof, making it wet, or resulting in what is called "sweating." It is also caused by capillary attraction acting through the butt ends of the shingles.

40. The *third* method of laying shingles (see Fig. 39) is on matched boarding *a* covered with roofing felt *b*; the lath *c* is then nailed on, the same as in the first method, and the shingles are laid on the lath.

This method makes a very good roof, when the spaces between the ends of the lath are left open at the gables for ventilation; but when closed, as is usually the case, makes the poorest roof of all, as the closed air space only increases the condensation and hastens the destruction of the roof.

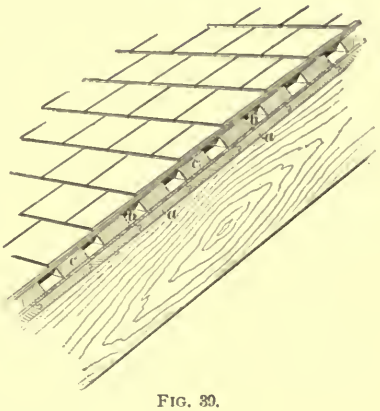


FIG. 39.

41. In laying shingles on a roof, the best results are obtained, and their endurance, which is the chief point, is vastly increased by setting the shingles from $\frac{3}{16}$ to $\frac{1}{2}$ inch apart. This allows the water to drain off rapidly, dries the roof quickly, and also allows for expansion and prevents buckling. Where narrow shingles are used, the joints should not be less than $\frac{1}{8}$ inch; while for shingles over 5 inches in width, from $\frac{1}{4}$ to $\frac{1}{2}$ inch joints should be allowed.

42. For covering conical roofs, the shingles should be selected in three or four widths, the largest butts being 5 inches at the gutter, and the smallest, 2 inches at the top. (See *a*, *b*, *c*, *d*, Fig. 40.)

To keep the shingles true to the radial lines, and the butts in line with the horizontal curves or courses running around the tower, a nail is driven into the center of the apex post *e*, to which a cord is attached. The starting course is laid horizontal with the eaves, the next gauge is laid off, and a shingle *g* is tacked in place. The cord is held to a joint of the first course under the tacked shingle, and a line is drawn through the center of the shingle *g* vertically; the cord is then moved to the outside corner of the butt, first on one side *h*, and then on the other side *i*: the side or taper lines *hj* and *ik* being drawn will be radial to the center of the apex, as shown by the plan *l*. The shingle, cut to the

lines marked, will form a templet for the first course. The shingles with 5-inch butts should be laid first, then the 4-inch, and so on until each lot is used, making a new templet as often as the joints begin to come too close.

This mode of application should be continued until the

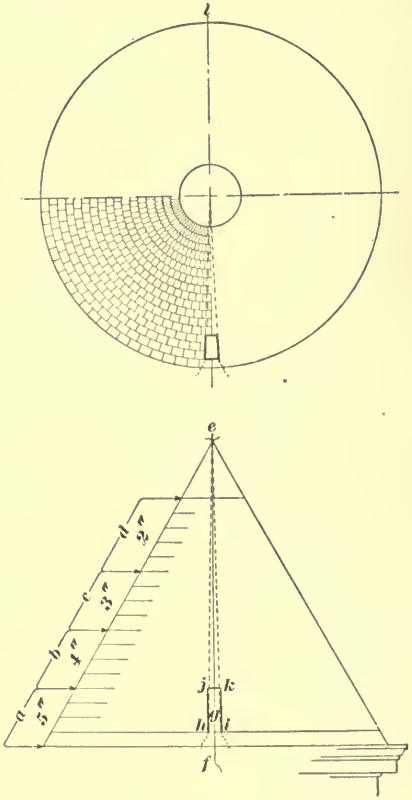


FIG. 40.

base of the finial is reached, when the apex should be flashed with tin if a wooden cap is to be used. If, however, a sheet-metal finial is required, the flashing may be omitted.

43. The gauge, or exposure to the weather, of a shingle is obtained by subtracting the lap from the length and dividing the difference by 3. Thus, for a shingle 18 inches long, and

with a 3-inch lap, the exposed length will be 18 inches − 3 inches = 15 inches, which divided by 3, will give 5 inches.

The number of inches exposed to the weather multiplied by the average width of a shingle gives the area of the exposure; dividing 14,400 (the number of square inches in 100 square feet) by the area of the exposure gives the number of shingles required to cover 100 square feet of roof. The average width of a shingle is, for example, 4 inches, and if exposed to the weather 4 inches, the area of exposure is 16 square inches; now 14,400 square inches divided by 16 gives 900, the number of shingles required per square.

44. The following table is arranged for shingles from 16 to 27 inches in length, and based on a given exposure to the weather:

TABLE 2.

Exposure to the Weather. Inches.	Number of Square Feet of Roof Covered by 1,000 Shingles.		Number of Shingles Required for 100 Square Feet of Roof.	
	4 Inches Wide.	6 Inches Wide.	4 Inches Wide.	6 Inches Wide.
4	111	167	900	600
5	139	208	720	480
6	167	250	600	400
7	194	291	514	343
8	222	333	450	300

TIN ROOFING.

TIN AND TIN PLATE.

45. **Tin,** when pure, is a metal of whiteness and brilliancy next to silver. It is highly malleable, but inferior in ductility and tenacity to all metals, except lead. Little affected by the atmosphere, at ordinary temperature, it is extensively used in manufacturing tin plate. Tin is not

a widely distributed metal; on the contrary it is extremely scarce and very rarely found in the natural or pure state.

Of tin ore there are two kinds, *tin stone* and *tin pyrites.* It is found principally in Cornwall, England; Bohemia and Saxony in Continental Europe; in the Malayan Peninsula; Australia; and more recently, in the United States of America.

46. Tin plate is sheet iron or steel coated with tin. The plates of sheet iron are first well cleaned by washing, then dipped in melted tin, and afterwards in a solution of diluted sulphuric acid, this last process being known as *pickling.* The sheets are then scoured with fine sand and water and afterwards dried. To obtain the proper softness, they are next annealed, sorted, and passed between rollers which impart to them an even thickness. This rolling hardens the plates, after which they are again annealed, sorted, pickled, and trimmed.

The sheets, by this process, go through six different baths: (1) the tinman's pot, containing grease; (2) the tin pot, containing melted tin; (3) the washing pot, containing melted tin, covered with grease in one compartment; (4) the plates are then brushed to remove excessive tin, then dipped in the other compartment containing the purest of tin; (5) the cold pot, containing tallow heated to a low temperature; (6) the list pot, containing tin, in which the edges of the plates are dipped.

Crystalline tin is produced by the application of a mixture of diluted nitromuriatic acid, for a few seconds, to heated tin plate, then washing the plate with water and drying.

47. The tests for tin plate are for ductility, strength, and color. To possess these attributes, the iron must be of the best quality, and the process of tinning must be conducted with skill.

Good tin plate is determined by the following conditions: The sheet should bear cutting into strips of a width equal to ten times the thickness of the plate, both across the fiber and

in line therewith, without splitting. These strips must, while hot, stand the strain of being bent on a mold, the circumference of which is equal to four times the width of the strip. The plates when cool must bear bending on a heading machine to such an extent as to form a cylinder whose maximum diameter shall be equal to sixty times the thickness of the plate. If there be any suggestion of lead in the tin, apply to the latter a few drops of pure acetic acid, and a whitish coating will appear. Add to this a few drops of potassium chromate solution. If it turns yellow, the tin has lead in it; the more lead the deeper the yellow.

48. Manufacturing Terms.—The term *tin plate* has been defined. *Terne plate* is a plate of sheet iron coated with tin and lead, and is inferior in quality to tin plate. Plates in the market are known as *charcoal* and *coke* plates. These terms, derived from the process of making the iron, are used to designate the grade of plates, when marking the boxes containing the goods.

Brands are the different marks or devices used by makers. Reliable manufacturers always endeavor to maintain a uniform grade of merit in the different brands they turn out.

Gauge denotes the thickness of the plates, and is known by such signs and marks as **I C, I X,** etc. **I C** represents a plate in gauge about No. 29, and weighing about 10 ounces to the square foot. **I X** corresponds to No. 27 gauge, and weighs nearly 12 ounces to the square foot.

Sizes of the plates are marked on the boxes. The common sizes are: 10 in.×14 in., 14 in.×20 in., 20 in.×28 in., etc.

Waster is an imperfect plate.

MATERIALS USED IN METAL ROOFING.

49. Solder is an alloy of two or more metals. When melted, it adheres strongly to the clean surfaces of the other metals less fusible. Solders are hard or soft, according to their relative fusibility. The following table gives the compositions and fusing points of different varieties:

TABLE 3.

COMPOSITIONS AND FUSING POINTS OF SOLDER.

Kind.	Hard.			Soft.			Fusing Point.
	Zinc.	Copper.	Silver.	Tin.	Lead.	Bismuth.	
Spelter, hardest	1						700°
Spelter, hard	2	3					550°
Spelter, soft	1	1					
Spelter, fine	2	2	$\frac{1}{4}$				
Silver, hard		1	4				
Silver, medium		1	3				
Silver, soft		1	2				
Plumbers', coarse				1	3		480°
Plumbers', ordinary				1	2		441°
Plumbers', fine				2	3		400°
Tinners'				1	1		370°
For tin pipe				3	2		330°
For tin pipe				4	4	1	

50. When solder becomes impure from use, it may be restored by heating it to 800°, and adding some sulphur, the mixture being well stirred. The sulphur, combining with the oxides and wastes of the metals, comes to the surface, where it can be skimmed off. By cooling to 400°, and putting in a little tallow to remove the sulphur, and adding tin, the proper quality may be restored.

Too much lead in solder produces a cellular joint and prevents its sweating properly.

Solder may be tested by melting, when, if a great many bright spots appear floating on top, it must be considered too soft or fine, while if the spots are totally absent, it contains too much lead. Tin spots about $\frac{3}{8}$ of an inch in diameter indicate good solder.

51. Fluxes are used to aid in the fusion of solder, and to clean the surfaces of metals to be joined. Those commonly used, and the metals to which they are applied, are as follows:

Flux.	Metals to be Joined.
Rosin	Lead, tin, or tinned metals; used with blowpipe.
Tallow	Copper and iron; used with blowpipe or bit.
Sal ammoniac	Dirty zinc; used with copper bit.
Muriatic acid or Hydrochloric acid	Clean zinc, copper, tin, or tinned metals; used with bit or blowpipe.
Chloride of zinc	Lead and tin tubes; used with copper bit or blowpipe.
Borax	Iron, steel, copper; used with blowpipe.

52. The melting points of the metals used in roofing are given in the following table:

TABLE 4.

Metal.	Melting Temperature.
Tin	446°
Copper	2,100°
Zinc	680°
Lead	626°
Wrought iron	2,732°

The fusing point varies greatly, according to the purity of the metal, while the fusing points of alloys vary with their composition.

53. Wall Hooks and Roofing Nails.—*Wall* or *flashing hooks*, as shown at (*a*), Fig. 41, or *b*, Fig. 42, hold the flashing in place where it lies against the wall, or they are driven

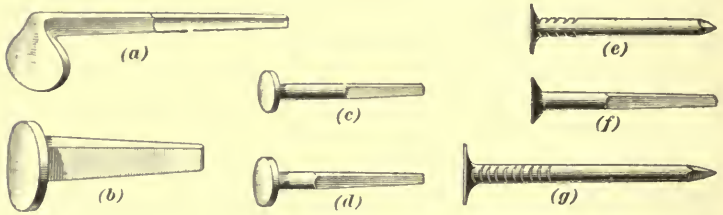


FIG. 41.

over the apron flashing to prevent it from pulling out; they are usually placed at about 16-inch centers.

Wall nails, as shown at (*b*), Fig. 41, are used for the same purpose, but are not so good, as only the shoulder, or under side of the head, bears against the flashing.

These wall hooks and nails should be of galvanized iron or of composition metal to prevent the corrosion of the metals they hold in place.

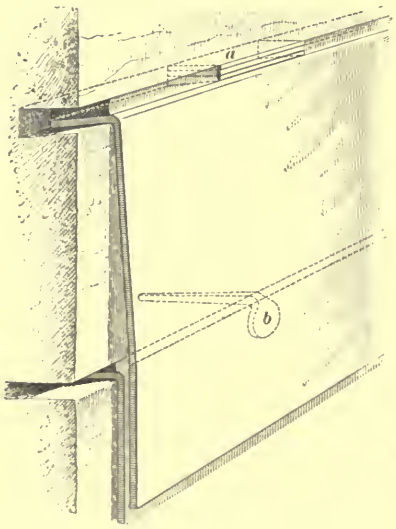


FIG. 42.

Tile, shingles, and slate are nailed to the roof with both *cut* and *wire* nails. For shingles or small slate, a cut nail (*c*) or (*d*), or a wire nail (*e*), Fig. 41, of a length equal to the thickness of the roof-boards should be used. These nails should be galvanized or tinned. The clean-cut steel nail, with countersunk head shown at (*f*), is generally used for slate.

The copper wire nail (*g*) is used for tiling, and the size is regulated by the kind of tile used and the thickness of the boarding. The thickness of the tile, plus the board thickness, gives the length. Cut

and wire steel nails, galvanized or tinned, are also used for tiles.

For composition roofing, the clout nail (*c*) and (*d*), Fig. 41, should be used, with or without a tin collar. Composite nails are preferable for all kinds of roofs where nails are used. The best are made of 7 parts copper and 4 parts zinc. By their use the dangers of corrosion and galvanic action are avoided or reduced to a minimum.

Where flashings are placed in a raglet in stonework, they are held by wood or lead plugs or bats; lead is preferred, as it permits more driving. These bats (see *a*, Fig. 42) are made up of pieces of lead $1\frac{1}{4}$ inches long by $\frac{3}{4}$ inch wide, until a thickness suitable to the joint is formed. They are placed at 12-inch centers, and are driven in and calked in place.

LAYING TIN ROOFS.

54. The methods for laying tin roofs vary. The *flat* seam, secured with either nails or cleats, is used on flat-pitched roofs; the *standing* seam is used on steep-pitched roofs, and occasionally on flat parts of such roofs, known as *decks*.

Of the first two methods of laying a tin roof, the one in which the seam is secured with cleats is to be preferred, the objection to the other being that the nails make holes in the tin, and as the tin expands or contracts, the holes become larger and the nails work loose.

55. Boarding for the roof should be matched and of even thickness, so that the surface shall be smooth and free from all rough spots or ridges; if possible, the boards should run lengthwise with the current or pitch, that is, the direction in which the water will flow when the roof is completed.

56. *Felt paper* under tin is of much advantage, and should be used. It prolongs the life of the tin; excludes any injurious vapors, gases, or fumes, which might reach the

tin from the rooms below; protects the tin from any injurious substances in the roof boards; and prevents "sweating."

57. The preparation of the sheets for laying, which should be carried out at the tinner's, consists of edging, that is, turning the edges of the sheets to form the seam. The upper and right-hand edges are turned up; the lower and left-hand edges are turned down.

In laying a tin roof, a start should be made at the lower left-hand corner of the roof, the course of which should lock

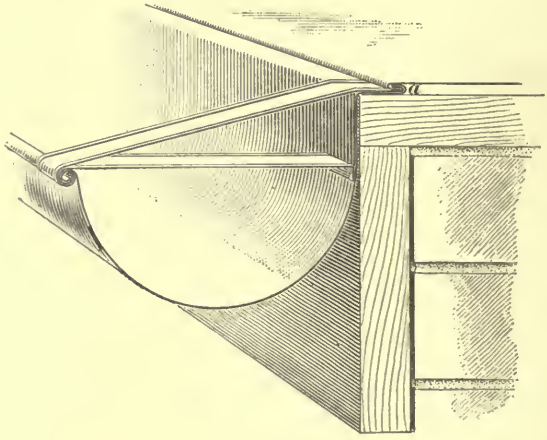


FIG. 43.

into the gutter seam *a*, as shown in Fig. 43, or into an eaves flashing. If the gutter is supported by straps, these should also be locked into the same seam.

In Fig. 44 is shown the flat seam roof secured with nails, which are put in as each sheet is laid. These nails should not be spaced further apart than 6 or 7 inches, and should be so placed that the nails of the last sheet will not come over those of the preceding ones.

In a 10″ × 14″ sheet there will be three nails, as shown at *a*, Fig. 44; while, by reason of the lock seams, the sheet will be further secured by the adjoining sheets and the nails in them. A sheet 14 in. × 20 in. will have five nails, and

one 20 in. × 28 in., six nails. In exposed locations the number of nails should be increased, so that a firm and rigid surface can be obtained.

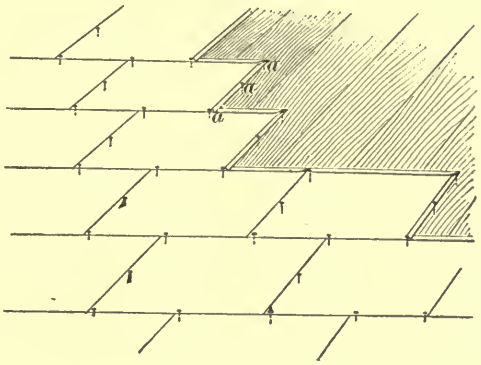


FIG. 44.

As shown at *a*, Fig. 45, the nails are covered by the overlapping edges of the next sheet, and also by the course above. After the tin has been nailed to the roof, the next process is to mallet down the seams; the quality of the roof to a great extent depending on the skill with which this operation is performed. Care should be taken not to break the seams, and to lay them evenly. The horizontal seams make the straight lines, while the other seams break joint, as shown in Fig. 44.

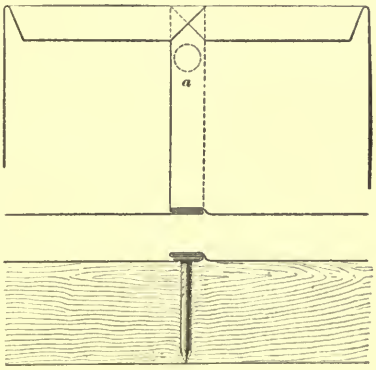


FIG. 45.

58. Flashings for skylight curbs, bulkheads, etc. are shown in Fig. 46; those for fire and gable walls, with apron or counterflashings, are indicated in Fig. 47.

The curb flashing (see *a*, Fig. 46) is nailed on top of the

curb *c* at *b*, is turned down against it to the roof, then carried over the fillet *d* out on the roof and seamed and locked to the roof tin at the joint *e*.

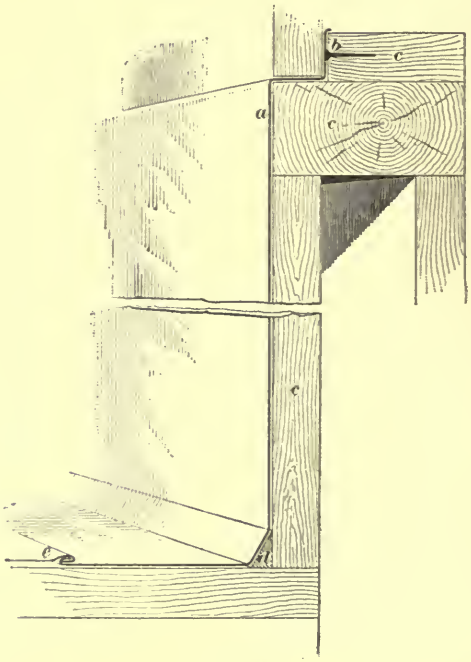


FIG. 46.

The wall flashing is placed in a raked-out joint *a*, Fig. 47, is secured with flashing hooks, turned down and over the fillet *b* to meet the roof tin *c*, and the two are seamed together. The apron flashing *d* is placed in the joint *e* and nailed with flashing hooks; it laps over the wall flashing about 4 inches. The joints *a* and *e* should be pointed with mastic or elastic cement.

59. The next process is soldering the seams. For joining tin, the solder should be composed of one-half tin and one-half lead. This solder is known and branded as *half-and-half*. After the seams have been resined, the solder is

applied by a flat-bottomed copper of sufficient size to melt the solder and keep it flowing. A small copper should not be used, because it does not hold heat well and produces, in consequence, an uneven seam without soaking the solder back into the crevices. Resin should be used as a flux for soldering tin; acid must not be used, for while it does as well for soldering as resin, it is likely to be driven into the seams and attack the metal.

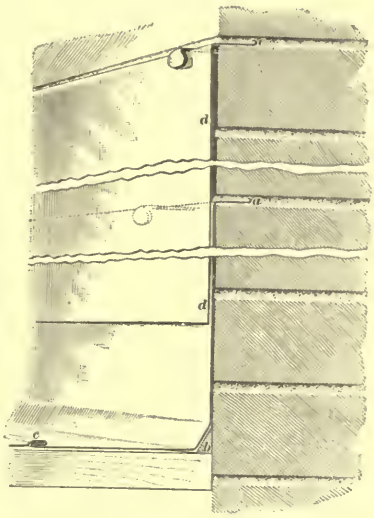


FIG. 47.

60. Fig. 48 illustrates the method of laying the tin with cleats. There are two nail holes made through the sheets, and the manner of fastening the cleat to the roof is such as

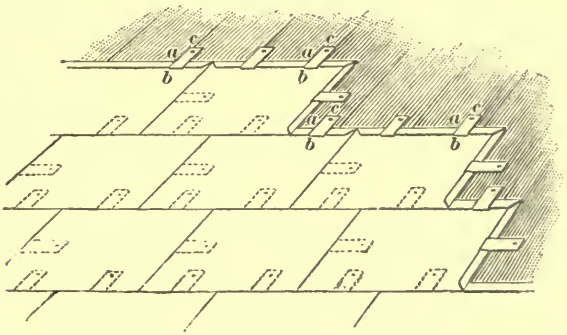


FIG. 48.

to permit all necessary contraction and expansion, without injury to the roofing material.

The cleat *a* consists of a simple strip of tin, from 2 to 3 inches in length, and from 1 to 1½ inches in width. One end *b* is bent to the same shape as the corresponding edge

of the plate locking into it. The overlapping edge of the upper sheet covers the cleat. The nail is driven near the opposite end of the cleat, as shown at *c*, but so far removed as to have no effect on the expansion and contraction of the sheets. In consequence, no strain is produced on the seams. The strips, it may be noticed, are nailed to the board direct, and the next sheets cover them.

61. A **standing seam** is shown in Fig. 49. The sheets are bent up at the edges, which is done at the shop, the left-hand edge *a* about $1\frac{3}{8}$ inches, and the right-hand edge *b* about 1 inch. Between the sheets a cleat *a* (see Fig. 50) is nailed before the next sheet on the right is placed. The cleat is 2 inches wide and its height is equal to the height of the left-hand standing edge of the sheet of roofing. Cleats should be spaced near together for steep roofs; for decks the spacing is usually the same as in flat roofs, or about 16 inches apart. There should be at least one cleat to each sheet of tin. The horizontal seams, as shown at *b*, are always flat like the flat-seam roof.

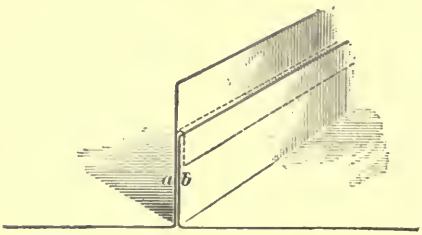


FIG. 49.

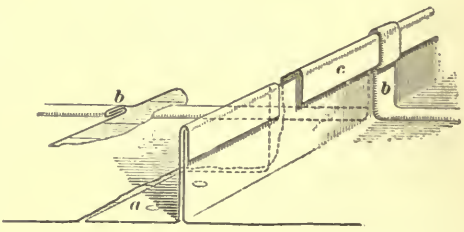


FIG. 50.

These seams may be either single lock, as at (*a*), or double

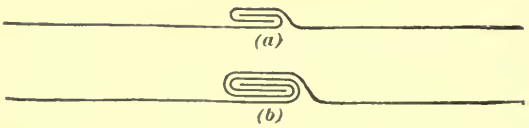


FIG. 51.

lock, as at (*b*) in Fig. 51. After the metal covering has been put on, the part of the left-hand sheet projecting above the right (see Fig. 49) in the vertical seams, is turned over and down with a seamer, as at *c*, Fig. 50.

62. *Nails* for tin roofs of all styles should have a length slightly less than the sum of the thicknesses of the roof boards, the felt and the tin, in order that they may not protrude below the lower surface of the sheathing.

The nails commonly used are similar to slaters' nails. They are thick, some having a slight bulge in the center, and are strong enough to drive through the thickest tin. Neither iron nor tin-coated, but zinc or galvanized nails should be used. The zinc produces a rough surface, tending to prevent the nails from drawing out.

63. For the sake of economy, sheets of 14 in. $\times$ 20 in. or 20 in. $\times$ 28 in. are generally used for roofing purposes.

Measurements in roofing are based on the square of 100 superficial feet; hips, valleys, and flashings are measured by the lineal foot, as are also gutters, down spouts, leaders, or conductors.

One sheet of tin 14 in. $\times$ 20 in. covers $235\frac{3}{16}$ square inches, or 1 foot $7\frac{1}{2}$ inches, of standing-seam roof. A box of 112 sheets covers 182 feet 14 inches of roof, allowing 1 inch and $1\frac{1}{4}$ inches for the two side seams, and $\frac{1}{4}$ and $\frac{1}{2}$ inch for top and bottom seams, respectively. In these calculations, no allowance is made for waste of any kind. One sheet of 14 in. $\times$ 20 in. covers 255 square inches, or 1 foot $9\frac{1}{4}$ inches of flat-lock roofing, and a box of 112 sheets, allowing $\frac{3}{8}$ inch all round for joints, covers 198 feet 3 inches.

64. The following table gives the size, grade, etc. of tin plate in general use:

TABLE 5.

Size. Inches.	Grade.	Sheets in Box.	Lb. in Box.	Gauge.
14×20	IC	112	113	29
14×20	IX	112	143	27
14×20	IXX	112	162	26
14×20	IXXX	112	182	25
14×20	IXXXX	112	202	24
20×28	IC	112	224	29
20×28	IX	112	280	27
20×28	IXX	112	322	26
	Terne Plate.			
14×20	IC	112	112	29
14×20	IX	112	140	27
20×28	IC	112	224	29
20×28	IX	112	280	27

65. The following table shows the length and diameter of leader pipes made from stock sizes of tin, and the length of pipe that may be made from 1 box of tin:

TABLE 6.

Sheets.				Boxes.	
Diameter of Pipe in Inches.	Number of Sheets.	Size of Sheets in Inches.	Length of Pipe in Feet and Inches.	Number Sheets in Box.	Length of Pipe in Feet.
$6\frac{1}{5}$	1	14×20	1′ $1\frac{1}{2}$″	112	126
$4\frac{1}{3}$	1	14×20	1′ $7\frac{1}{2}$″	112	181
4	2	14×20	3′ 3″	112	182
$3\frac{1}{8}$	1	14×20	2′ 3″	112	252
$2\frac{1}{8}$	1	14×20	3′ $4\frac{1}{2}$″	112	378

If, for example, the leader pipe is to be 4 inches in diameter, and the circumference $12\frac{1}{2}$ inches, it is plain that only one length can be had out of the 14 in. $\times$ 20 in. Allowing $\frac{1}{4}$-inch lap for each joint at top and bottom, and using two sheets for a length of pipe, we have 20 in. $\times 2 - 1$ in. $= 39$ inches, or 3 feet 3 inches; and 39 in. $\times 56$, half the number of sheets in a box, gives 182 feet, the length of leader sections that may be constructed from 1 box.

66. The following table gives length of semicircular eaves gutters that may be made from 1 box of tin:

TABLE 7.

SEMICIRCULAR EAVES GUTTERS.

Sheets.				Boxes.	
Girth. Inches.	Number of Sheets.	Size of Sheets. Inches.	Length of Gutter in Feet and Inches.	Number Sheets in Box.	Length of Gutter. Feet.
19	1	14×20	$1'\ 1\frac{1}{2}''$	112	126
13	1	14×20	$1'\ 7\frac{1}{2}''$	112	182

SHEET-METAL SHINGLES.

67. Metal shingles take the place of tile, wooden shingles, slate, and other roof coverings. On a pitch of over 30° they make a light and effective roof. They are made of tin, zinc, galvanized iron, copper, bronze, and composition metal, and are manufactured in a variety of shapes and designs. They usually come in single pieces, each forming one shingle, but many makers also furnish a sheet with four shingles stamped on it. Metal shingles are, as a rule, named from their form of outline, and are designated as *Gothic*, *diamond*, *hexagonal*, etc.

68. Laying Metal Shingles.—Generally these shingles

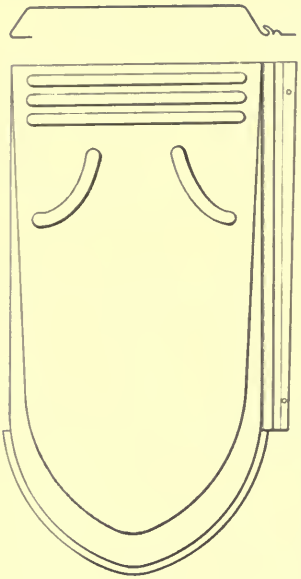


FIG. 52.

are laid from the eaves up to the ridge. There is, however, a method of laying the shingles from the ridge downwards. In laying shingles of the Gothic pattern (one of which is shown in Fig. 52), the gutter and eaves flashing should be set as shown at *a*, Fig. 53, the flashings being carried up about 6 or 8 inches on the roof boards. A start should be made at the lower left-hand corner, care being taken that the start is made straight with the eaves. The shingle point should be set back 2 or more inches, and nailed through the flange *b*. As each row is laid, the gable end flashings *c* should be attached as shown.

The ridge is finished as shown at *a*, Fig. 54, and is put in

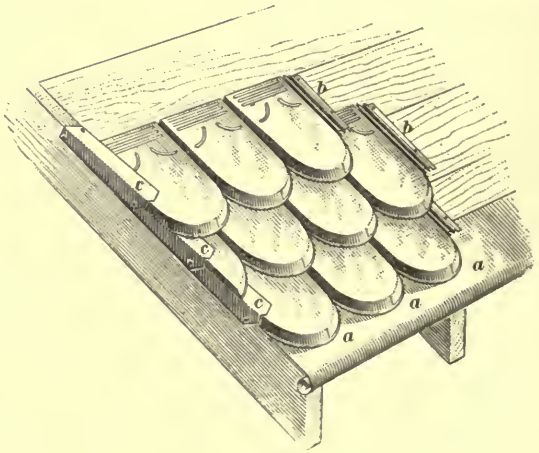


FIG. 53.

place before the last tier of shingles is laid. In the case of

a whole shingle not working and fitting into the grooves *b* of the ridge, it should be cut to the proper length.

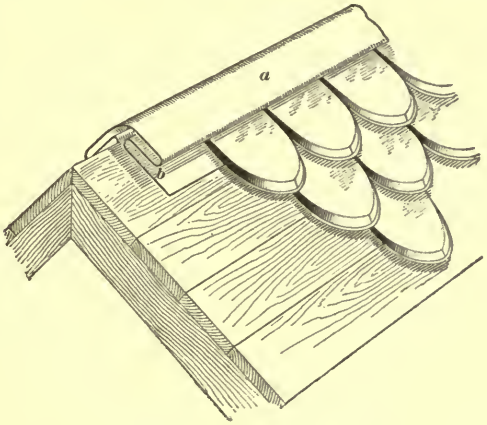


FIG. 54.

69. Flashings.—*Hips* are finished as shown at *a*, Fig. 55. The edges of the shingles should be cut to the proper angle and fitted into the groove *b* of the hip flashing.

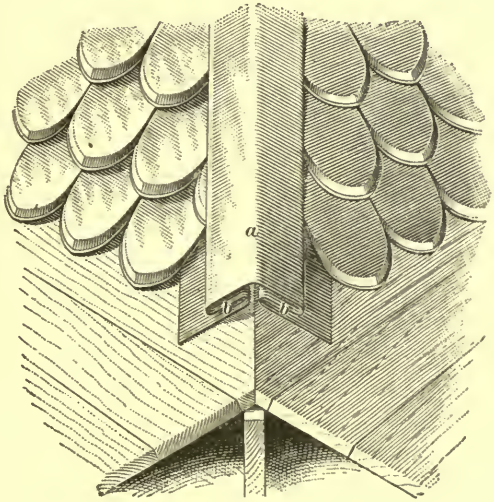


FIG. 55.

Valley flashings, as at *a*, Fig. 56, should be made with a lock or fillet *b* at the edges of the gutter portion.

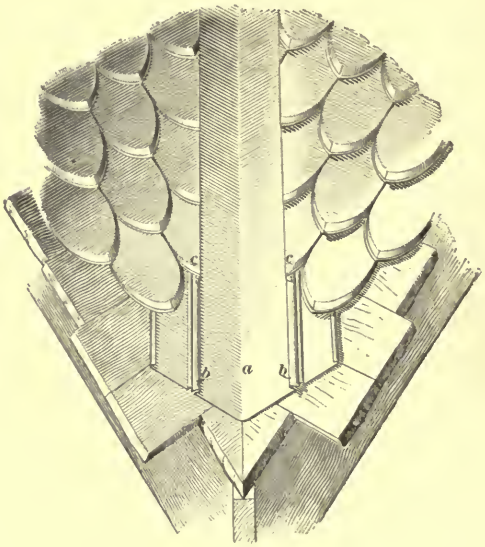


FIG. 56.

The edges of the shingles should be trimmed to the proper angle and turned over with a pair of hand tongs. The edges of the shingles should be made to clasp the edges of the valley fillet.

The chimneys and wall junctions are flashed as indicated in Fig. 57. The brick joints, as at *a*, are raked out, and a flashing of tin, of the shape shown at *b*, is formed with a groove into which the shingles are pushed. The flashing, having been inserted into the joint *a*, is secured to the wall with flashing hooks *d*, *d*, and the joint is carefully repointed with elastic cement.

Dormers and skylights may be flashed as shown in Fig. 58. The flashing *a* is turned up against the sheathing boards *b* and under the clapboards *c*, or other vertical side covering; the edges of the shingles are then carried up and fitted into the grooves.

The gable cap and flashing used with square-tailed

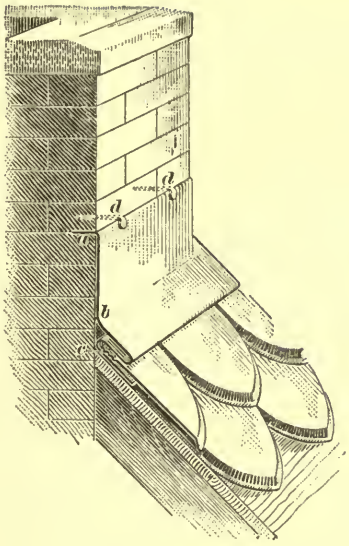


FIG. 57.

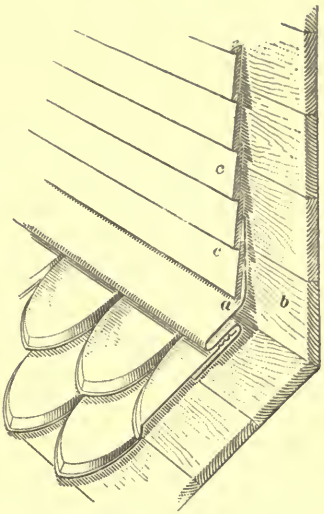


FIG. 58.

shingles are indicated in Fig. 59. The molding *a* caps the start of all the rows of shingles and laps over the barge board *b* to which it is nailed.

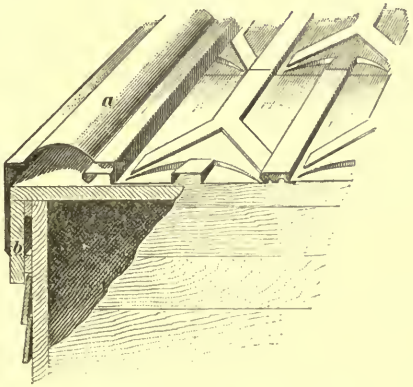


FIG. 59.

70. Diamond-shaped shingles, as shown in the views (*a*), (*b*), and (*c*), Fig. 60, are laid in the same general manner

as the Gothic, with the exception that the start may be made from either the right or left hand, as the case may require. The fillet *a* on the two upper flanges becomes a water-tight

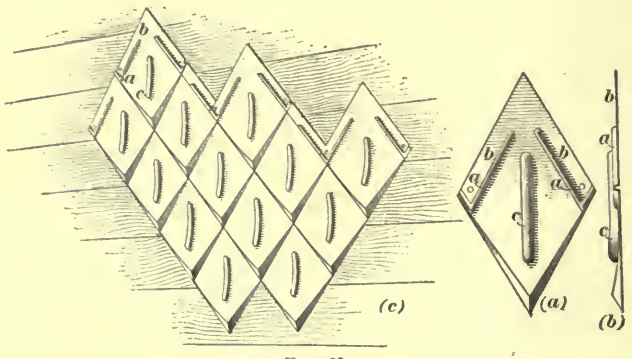


FIG. 60.

joint. The shingle is nailed through the lower edge of the flange *b* on each side. The central longitudinal rib *c* imparts rigidity and adds to the effect.

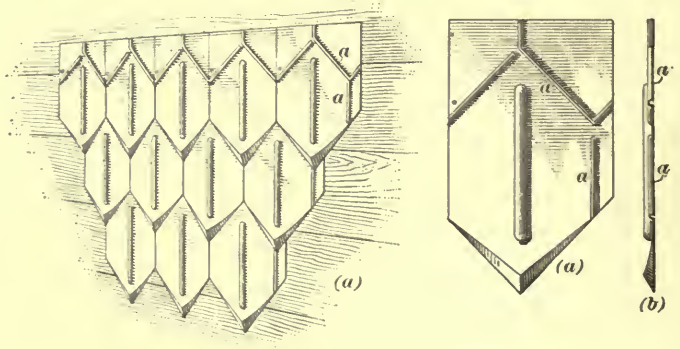


FIG. 61.

Hexagonal shingles, Fig. 61, are of the same construction as the diamond, save for the right-hand flange *a*, which is extended. The additional fillet necessitates the laying of these shingles from the left to the right.

71. The method of laying tile shingles, from the ridge to the eaves, is shown in Fig. 62. The ridge cap is the same

as that used in the other methods. The lower flanges *a* of the shingles are made with a groove *b* into which the next

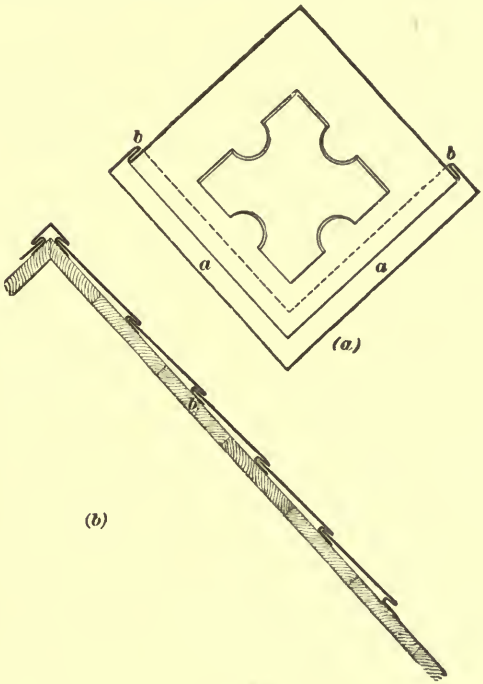


FIG. 62.

course fits. The chief advantage of these shingles is that all scaffolding is removed as the roof is laid, and all difficulty in making a tight joint at the point of support for the scaffold is obviated.

COPPER ROOFING.

PROPERTIES OF COPPER.

72. Copper is distinguished from all other metals by its peculiar red color. Its resistance to corrosion when exposed to the atmosphere, combined with its lightness, gives it great value as a roof covering. Copper is very malleable

and ductile, and also tenacious; it is found in most countries, the principal mines being those on the shores of Lake Superior, in the United States of America, and at Corocoro, Bolivia, South America.

73. Sheet Copper.—Copper is obtained from its ore by the following process: First, the ore is roasted or calcined; after the roasting, it is melted in a reverberatory furnace, whence it issues in the state called *coarse metal;* this metal is then stamped and pulverized, passed through a furnace, and afterwards melted; the resulting pure metal is roasted and then refined. The copper is then cast into ingots and afterwards rolled into sheets, which are cut to market sizes, varying from 24 in. × 48 in. to 48 in. × 72 in., and are supplied in two forms, soft or annealed, and hard or cold rolled. Both varieties may be tin plated or "tinned," when desired.

74. Tests.—The qualities determining the suitability of the sheets for roofing are ductility and strength, and uniformity of gauge or thickness. The sheets must stand bending with and across the fiber, without yielding even to repeated attempts at splitting and breaking. The gauge, which varies from 1 to 30, must be as represented, and tested with a wire gauge, and the sheet must be of the full weight, corresponding to the gauge, which, in common use, ranges from 10 to 20 ounces per square foot. When a piece is broken off, the fiber should present a bright, lustrous, and silky appearance, if the copper is of the best grade. The metal should also bear stamping into form without developing fractures.

LAYING COPPER ROOFS.

75. The methods employed in laying copper roofs are usually the same as those required for tin roofing, though the flat roof laid with a lap seam is not to be commended. It is weak, and, being soldered and nailed, will not permit sufficient expansion and contraction. Where solder is used, the lock seam with cleats is best. The edges of the sheets

and all surfaces with which they come in contact should, before the seaming and folding are done, be thoroughly cleaned with chloride of zinc. When the sheets are in place, mallet them down to the roof. In case the metal is tinned on one side, the folds should be turned so that the tinned surfaces shall face each other. Tinning is resorted to so that the solder may flow or sweat more freely than it will on the copper. The solder used for copper roofs is the same as for tin roofing, but with a flux of sal ammoniac.

The standing seam method of laying should be employed where extra strength and stiffness are required, on very steep-pitched roofs, and on flat surfaces where work without solder is to be carried out.

76. **Roll-joint** copper roofing is laid in two different ways. In the one the roll is hollow and is secured to the roof by *clips* or *tingles;* in the other a solid roll is used, set with a trough or nailed directly to the roof. Fig. 63 shows the hollow roll. The clips or tingles *a*, *a* are nailed to the roof before each sheet is laid; against the clips or tingles the edges of the sheets *b* are turned, and the left-hand sheet is bent over to form the lock *c*. This joint or lock is seamed and then turned over in a roll, as indicated by the dotted lines and the completed roll *d*.

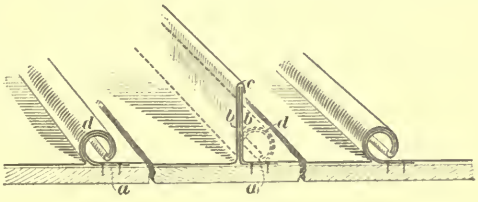


FIG. 63.

77. The **trough** method is illustrated by Fig. 64. The wood rolls *a* are $1\frac{1}{2}$ in. $\times 2$ in. The trough *b* made of copper, in which the rolls are set, is nailed to the roof boards; the sheets

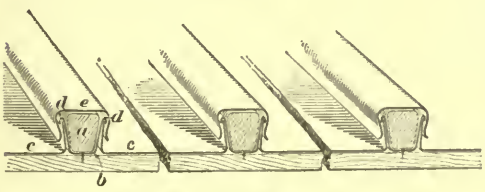


FIG. 64.

c are then bent up to the top of the trough and the edges *d* of the trough are locked or turned down over them. The cap *c* is made as indicated, and is sprung tightly over the roll. The other solid roll, shown in Fig. 65, has the roofing plate *a* bent up and over it, the upper sheet being the last

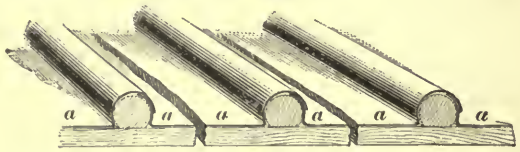


FIG. 65.

put in place between the rolls as the covering is laid. This, under ordinary circumstances, makes a good roof.

78. To save time and labor, flashings or other vertical jointed work should be soldered, when required, before being taken on the roof. When the sheets are in place, the solder will not flow into the vertical joints; but on the ground, the seams may be laid flat and the solder will readily soak in.

Connections between the flashings of the walls, chimneys, etc. and the gutters should be double locked, and to permit free movement, they should be unsoldered.

79. The gauge, thickness, and weight per superficial foot of copper used for roofing purposes, are given in the following table:

TABLE 8.

Gauge Number.	Thickness in Decimal Parts of an Inch.	Weight. Ounces per Square Foot.
29	.0134	10
27	.0161	12
26	.0188	14
24	.0215	16
23	.0242	18
22	.0269	20

COPPER TILES.

80. Copper roofing tiles are made in imitation of most of the different forms of terra-cotta tiles. They are extensively used, principally on account of their cheapness and lightness. Like all other tiles, they are generally laid by beginning at the eaves and continuing to the ridge. Great care must be taken in laying the first course, called *starters*. On this depends the appearance of the entire roof, for if the starters be out of line horizontally, the finishers at the ridge show the same defect; and should there be intercepting roofs, the defect will show at the valleys as well.

81. The most popular form used is the imitation of the Spanish clay tile, as shown in Fig. 66. This pattern is interlocking, and is secured to the roof with nails driven through the right-hand flange *a*. The fillet collar *b* near the upper end forms the horizontal joint with the tile above, and the sides connect with a vertical side lock, as shown at *a*, Fig. 67, rendering them water-tight. At *b*, Fig. 67, is the flange, which is nailed to the roof.

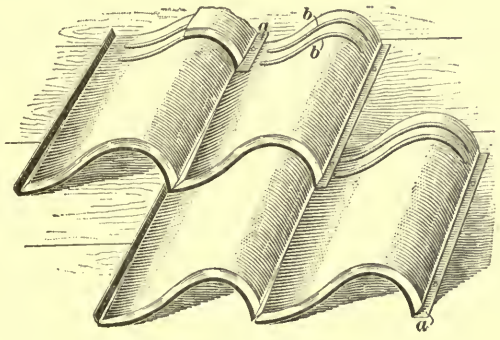


FIG. 66.

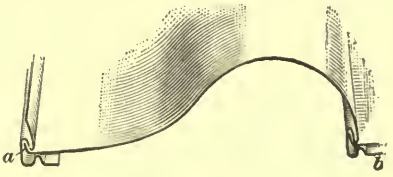


FIG. 67.

82. *Ridges* and *hips* are made in different forms to go with the tiles; the most common one is shown at *a*, Fig. 68.

On the hips the tiles must be cut to the proper angle and fitted to the hip strip *b*, the roll being placed over them and nailed through its flanges.

The valley tile must be cut in the same way, the open ends of the tile being closed with pieces cut to the shape of the tile and soldered in. Where these tiles are used, the valley flashing should never be less than 20 inches wide, and in nailing the tile over it, the nails must be well driven.

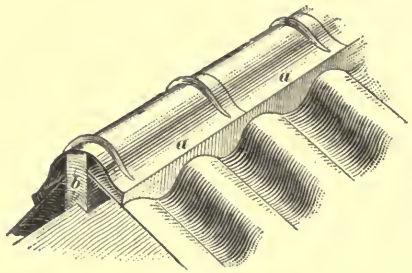


FIG. 68.

In nailing the gutter tile in place, care must be taken not to drive the nails into the gutter, under the side lock, as it would cause the roof to leak.

Flashings should be constructed in the manner shown under the head "Tin Roofing," and of 14 or 16 ounce metal. All valleys and gutters should be 16 or 18 ounce metal.

83. Conical-tower roofs may be covered with two kinds of special tile, graduated to correspond to the pitch; of these, one is made flat and the other round, as shown at (*a*) and (*b*), Fig. 69.

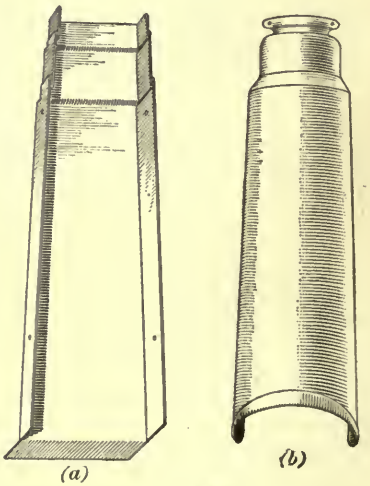


FIG. 69.

The roof is prepared for these tiles by attaching wedge-shaped strips, as *a*, Fig. 70, to the sheathing, the edges of the flat portion of the tile being nailed to the strips

as shown at *b*. The round tiles are placed over the strips, lapping the upturned edges of the flat tiles. They are nailed through the strips at the upper end *c*, and the lower, or butt, end *d* nailed into the end of the strip.

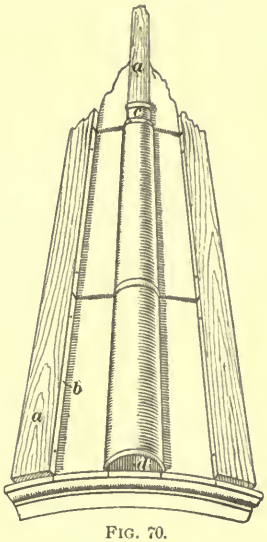


FIG. 70.

84. For straight surfaces the following sizes of tiles are used: 7 in. × 10 in., 10 in. × 14 in., and 14 in. × 20 in. The last is better adapted to large roofs, but for ordinary roofs 10 in. × 14 in. is the size recommended. These tiles may be made of 12, 14, or 16 ounce copper.

A square will require four hundred 7 in. × 10 in. tiles; one hundred and seventy-four 10 in. × 14 in. tiles; or seventy-two 14 in. × 20 in. tiles. These quantities allow for laps, waste, cutting, etc.

GALVANIZED SHEET-IRON ROOFING.

85. Galvanized iron is iron coated with zinc, the object being to protect its surface from the rapid oxidation taking place when it is exposed to atmospheric influences. The zinc coating is applied to the plates while they are heated, the plates being previously prepared by cleaning and dipping in various chemical solutions, as sulphuric acid, and the salts of chloride of zinc, or sal ammoniac. The coating should be of uniform thickness and should cover the entire surface.

86. To test the quality of galvanized iron, make a double seam and mallet it down close; if it shows no fracture the iron is of a good quality. A more severe test is to again flatten out the joint or seam so made, without the material showing fracture. Samples may be tested for thickness of coating by greasing them and holding them

over a gas jet with a pair of pliers; the amount of fusible metal flowing off will determine the character of each sample.

87. The ordinary sheets in use are from No. 16 to No. 28 gauge, and vary in weight from No. 16 at 3 pounds per square foot down to No. 28 at $\frac{3}{4}$ pound per square foot.

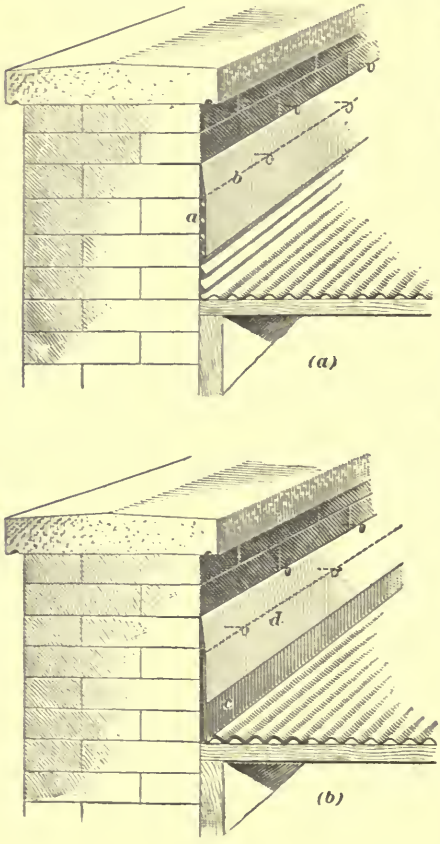


FIG. 71.

88. *Corrugated* sheets may be placed on boards or applied direct to the rafters; flat sheets may be laid on boards, divided by wood rolls into panels. In either case, felt or paper should be placed under galvanized-iron roofing, to prevent sweating. The sheets should have a lap of at least 4 inches on the roof boards. Where the sheets abut against a fire wall, an edge *a* should be turned up about 6 inches, secured to the wall with wall hooks, and covered with an apron flashing *b*, secured as shown at (*a*), Fig. 71; otherwise, first lay a flashing *c* and carry the roofing over it and counterflash as shown in (*b*), Fig. 71.

89. Ridges should be finished by a ridge roll or cap, as shown in Fig. 72 (*a*), having an apron or wing *b* corrugated

to suit the corrugations of the sheets, or, as indicated at (*b*), Fig. 72, a ridge board *c* having its lower face corrugated to match the sheets, may be attached to the roof and then covered with a plain cap *d*.

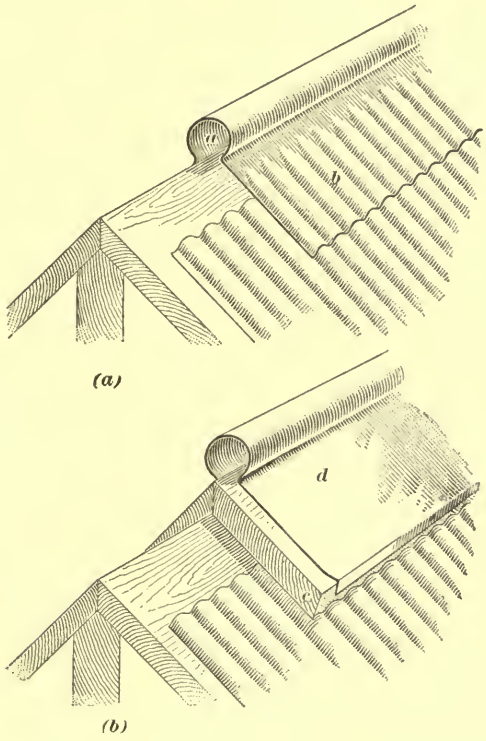


FIG. 72.

Hips should be finished as shown in Fig. 73, by cutting the iron sheet *c* to connect with the hip strip *b* and then covering the joint with a hip cap *a*.

Valleys should be formed of plain sheets of galvanized iron, from 18 to 24 inches wide, the ends being lapped at least 6 inches. Corrugated iron is cut to the proper angle and fitted over the valley, the sheets lapping for a distance of 6 inches over the edges. In fitting around chimneys, bulkheads, etc., the sheets on the lower side *a* and flanks *b*,

Fig. 74, should abut against the chimney; a flashing should be turned up against the chimney 5 or 6 inches, as at *c*, and counterflashed, as at *d*. The tops of the two flashings are secured with wall hooks.

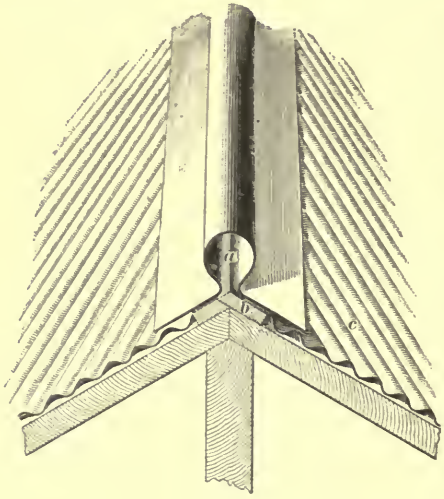


FIG. 73.

90. When used for siding, the sheets should have a lap of at least 1 inch at the ends and one corrugation at the edges of the sheets. The edge laps should be nailed every 6 inches, and the end laps in every other corrugation. If the metal is put on studding, the studs should be spaced to suit the width of the sheet used. If the height

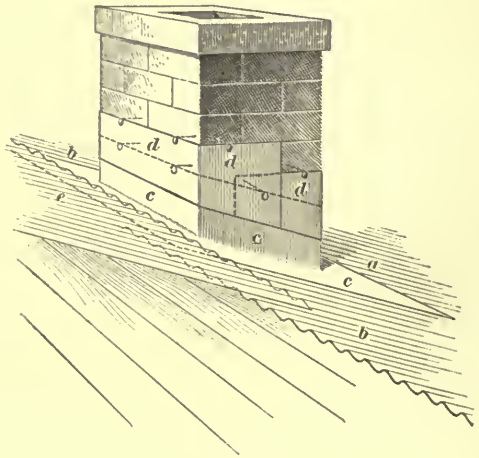


FIG. 74.

is greater than one sheet, a piece of studding should be put in horizontally, at the proper height, to take the end laps.

If applied to rafters without boards, the rafter must be spaced to suit the width of the sheets, and a piece of studding must be put in between each rafter where the sheets join at top and bottom, and also midway between, to prevent sagging.

Another method is to set the rafters to suit the width of the sheet and cover them with strong slats, bringing up the rafter edge with a piece of the same material.

91. In preparing the material for flat sheets laid with wood rolls, the sheets are riveted together, end to end, making a continuous sheet from eave to ridge; or each sheet may be laid with a lock seam, as described for copper roofs. The rivets should not be more than 1 inch apart.

The eaves gutter, or flashing, must be attached to the roof before laying the roof proper, and must lap the roof boards not less than 4 inches.

The wood rolls or strips *a* in Fig. 75 are attached to the

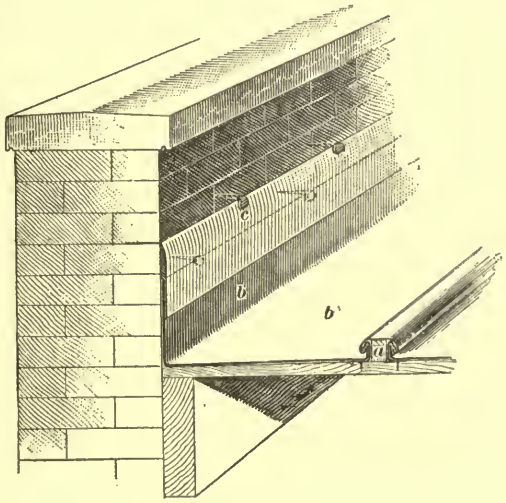


FIG. 75.

sheathing, and spaced to suit the width of the sheets. Against a fire or parapet wall, a sheet *b* will be required,

which will be counterflashed as at *c*. Clips 2 inches wide by 5 inches long should be attached to the edges of the rolls. The method of securing the sheets by the clips and rolls is shown in Fig. 76, in which *a* is the clip; *b*, the sheet; *c*, the

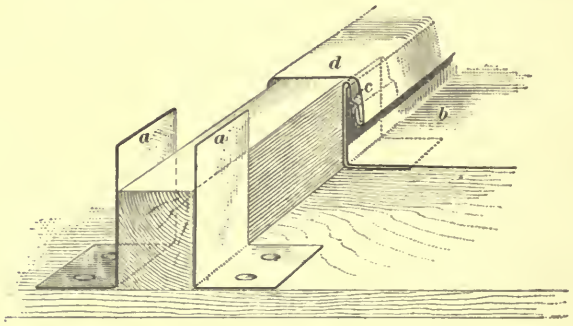


FIG. 76.

lock; and *d*, the cap roll. The cap roll is slipped over the wood roll, the edges of the roll passing over the throating formed by the ends of the clips *a*, *a*, which thus hold it in place. The horizontal end joints are made with a single lock and are secured to the roof by clips, in the same manner as in the roofing.

92. The following table gives the amount of galvanized corrugated sheet iron required to lay one square:

TABLE 9.

Side Lap.	Corrugation.	Length of End Lap.					
		1 in.	2 in.	3 in.	4 in.	5 in.	6 in.
One Corrugation Lap.	$2\frac{1}{2}$ in.	110 ft.	111 ft.	112 ft.	113 ft.	114 ft.	115 ft.
One and one-half Corrugation Lap.	$1\frac{1}{4}$ in.	110 ft.	111 ft.	112 ft.	113 ft.	114 ft.	115 ft.
	$\frac{3}{4}$ in.	105 ft.	106 ft.	107 ft.	108 ft.	109 ft.	110 ft.

The following table gives the width, depth, and number of corrugations to a sheet and the covering width, deducting lap.

TABLE 10.

Width of Corrugation. Inches.	Depth of Corrugation. Inches.	Number of Corrugations to Sheet.	Width of Sheet after Corrugation. Inches.	Covering Width after Lapping One Corrugation. Inches.
$2\frac{1}{2}$	$\frac{1}{2}$ to $\frac{5}{8}$	10	26	24
$1\frac{1}{4}$	$\frac{3}{8}$ to $\frac{1}{2}$	$19\frac{1}{2}$	26	24
$\frac{3}{4}$	$\frac{1}{4}$	$34\frac{1}{2}$	26	25

The following table gives the gauge, thickness, and weight, in pounds per square foot, of galvanized sheet iron:

TABLE 11.

Gauge Number.	Thickness. Inch.	Weight. Pounds Per Square Foot.
16	.065	3.00
17	.058	2.69
18	.049	2.31
19	.042	2.07
20	.035	1.75
21	.032	1.50
22	.028	1.32
23	.025	1.19
24	.022	1.06
25	.020	1.00
26	.018	0.96
27	.016	0.88
28	.014	0.75

BLACK SHEET-IRON ROOFING.

93. Black sheet iron for roofing is furnished cold rolled and annealed, in gauges ranging from 16 to 26 and in weight from $\frac{3}{4}$ pound to $2\frac{1}{2}$ pounds per square foot. Anything lighter

than gauge 26 is not recommended. The sizes of the sheets vary from 24 in. × 72 in. for the lighter gauges to 30 in. × 84 in. for the heavier weight. The sheets should be free from flaws or holes, and uniform in thickness and ductility.

Paper and felt are not, as a rule, used under iron, but their use, it should be observed, tends to make the roof more enduring, protecting it from gases underneath and from sweating.

94. Sheet iron is usually laid with some form of standing seam, with or without a cap, on the interlocking pattern, with the same kind of joint as in the case of metal tiles or shingles.

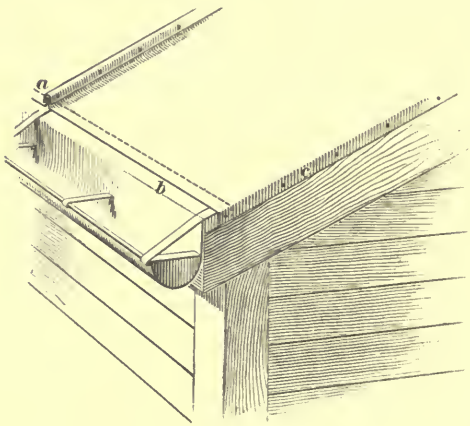


FIG. 77.

Standing seam roofing with cap is prepared by locking and seaming the sheets together, end to end, thus forming a continuous sheet the full length of the slope of the roof. The edges are then turned up or flanged 1 inch high (see *a*, Fig. 77). The flange *b* of the eaves gutter should lap on the roof 4 inches. The outside edge *c* is bent down over the gable facia at least 1 inch, and nailed. The standing seams are secured with cleats *a*, Fig. 78; these are made of metal 2

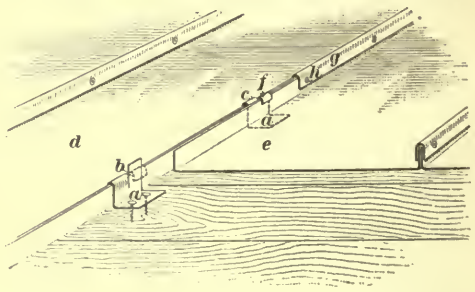


FIG. 78.

inches wide, having a bearing on the roof of 2 in. $\times 1\frac{1}{2}$ in. The upstanding part of the cleats is cut down the middle, as at *b*, $1\frac{3}{8}$ inches, and one section *c* of the divided cleat is bent over the flange of the sheet *d* first laid. The sheets of the second row *e* are then flanged and placed against the clip *a*, whose other half *b* is turned over this flange.

The flanges are then gone over, clamped or seamed up close and tight, and the cap *g* is put on. This cap should be clamped securely in place. Holes *h* are then punched through the cap and flanges about 15 or 16 inches apart, and $\frac{1}{8}$-inch rivets are used to bind the parts together. A washer should be placed on each end of the rivet, and the head should be formed with a rivet set.

Hips, in this style of roofing, are made by cutting the sheets to the proper angles, but making an allowance of 2 inches, then turning or flanging this 2-inch section, and capping it in the same way as the other joints.

Valleys are formed of full-width sheets, 24 inches broad. A $\frac{1}{2}$-inch single lock is formed on the sheets on each edge of the valley, which should be secured to the roof with clips to fit the lock, as in flat seam tin roofing. A flat lock is then formed on the roofing sheet, and both are locked together and seamed down.

Flashings are constructed in the same manner as for the metal roofs already described.

95. *Double-seamed* roofing, shown in Fig. 79, has another form of standing seam. This roofing is put up in rolls, the same as capped roofing, and the sheets are joined end to end by a single lock seam. It may be at once seen that with this roofing no caps or fastenings of any kind are used, except the cleats *a*, which are nailed to the roof at the same centers as for cap roofing. The sheets are turned up $1\frac{1}{4}$ inches on one side *c*, and $1\frac{1}{2}$ inches on the side *b*. The $1\frac{1}{2}$-inch side is turned over the $1\frac{1}{4}$-inch side, as at *d*, and the whole seam is then turned over and down again, forming the double seam *e*, from which the roofing obtains its name. The flashings are the same as those before described. This

method guarantees an enduring and perfectly water-tight roof.

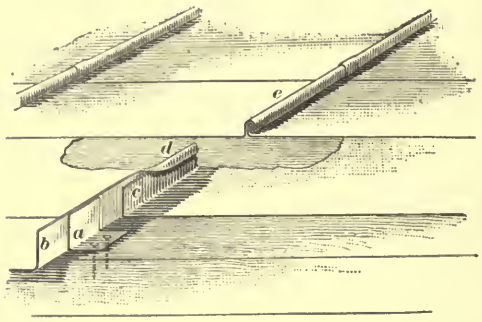


FIG. 79.

96. The *interlocking* pattern (see Fig. 80) consists of sheets with a single lock *a* at the top and bottom of the sheets, and at the sides a vertical lock *b*. The plates are attached to the roof by nailing through the side flange *c*. The chief merits of this method are that no cleats, rivets, or anchors are employed, and a great saving of time and labor

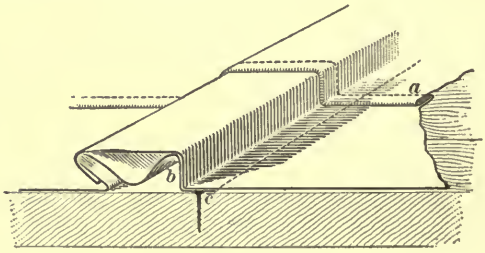


FIG. 80.

is effected. The roof appears as if laid with rolls, and the peculiar pattern of the side lock gives the roof strength and makes it very rigid and durable.

97. The following table gives the gauge, thickness, and weight, in pounds of black sheet iron per square foot:

TABLE 12.

Gauge Number.	Thickness. Inch.	Weight. Pounds per Square Foot.
16	.065	2.61
17	.058	2.33
18	.049	1.97
19	.042	1.69
20	.035	1.40
21	.032	1.28
22	.028	1.12
23	.025	1.00
24	.022	0.88
25	.020	0.80
26	.018	0.72
27	.016	0.64
28	.014	0.56

SHEET-LEAD ROOFING.

98. Lead, the softest metal in general use, is extremely plastic, very malleable, flexible, and heavy, but lacking in tenacity and elasticity. It is mostly found in combination with other ores, the principal mines being at Leadville, Col.; in Derbyshire, England; the Harz Mountains, Germany; and in the south of Spain.

Lead is reduced from the ore called galena, by roasting or smelting in a reverberatory furnace furnished with long flues, to catch the particles of lead precipitated by the fumes.

Sheet lead is either cast or milled. *Cast* lead is thicker and heavier than milled lead, and has a harder surface. Being, however, liable to flaws, such as sand holes, etc., and irregular in thickness, it should therefore not be used if lighter than 60 pounds per square foot.

Milled lead is rolled thin, is more uniform in thickness

than cast lead, bends easily, and when worked gives neater and better results, but cracks if much exposed to the sun.

Lead is always described by its weight per superficial foot, and not by gauge.

99. Roofs covered with lead should not have a pitch of more than 1 inch to the foot. Boarding under a sheet-lead roof must be more carefully laid than for any other metal; the boards should be narrow and matched, and run with the current or pitch. If the boards are not blind nailed in the joints, the nails should be set. The boards should also be well planed at the joints, to make a smooth surface, and, to prevent warping, should be thicker than is usual in such places. Planking $1\frac{1}{2}$ inches thick gives good results.

In sheet lead, it is best not to use sheets measuring more than 3 ft. $\times$ 8 ft., or $3\frac{1}{2}$ ft. $\times$ 10 ft., the expansion and contraction being in such a case liable to make the roof defective. The usual size is $2\frac{1}{2}$ ft. $\times$ 6 ft. The sheets of lead should not be secured by nailing or by soldering, but should be left free, to allow of sufficient movement.

100. The *junctions* employed in lead roofs are called **rolls** when laid in the direction of the pitch, and **drips** when laid at right angles thereto. The rolls are from 2 to 3 inches in diameter, having the upper surface round and the lower corners left square. See Fig. 65. The edges are called overlap or overcloak, the latter being the edge of the sheet turned over the edge of the succeeding sheet and dressed down, forming the roll. *Hollow rolls* for sheet lead are constructed in the same way as for copper roofs. See Fig. 63.

The *clips* or *tingles* between the sheets of a lead roof must not be spaced more than 20 inches apart.

Nosings (see Fig. 81) are the rolls formed at the angle between the horizontal surface of the flat and the sloping sides of the roof. The flashing *a* on the sloping surface is turned up and nailed to the edges of the flat or deck plank, and over this is nailed a wood nosing *b*. The edge of the sheet of the flat is locked into and secured by clips *c*, *c* let

into a rebate in the edge of the flat; the sheets *d* are then bent over the nosing in the form of a drip. See Fig. 81.

A **lock** or **welt** is an ordinary single lock joint used instead of a roll on flats, where there is a sufficent pitch; though it takes less metal, it is not recommended.

On hips and in valleys, a lapped joint is used. This is made by lapping one sheet 5 or 6 inches over an adjacent one, dressing the edges and malleting them down flat.

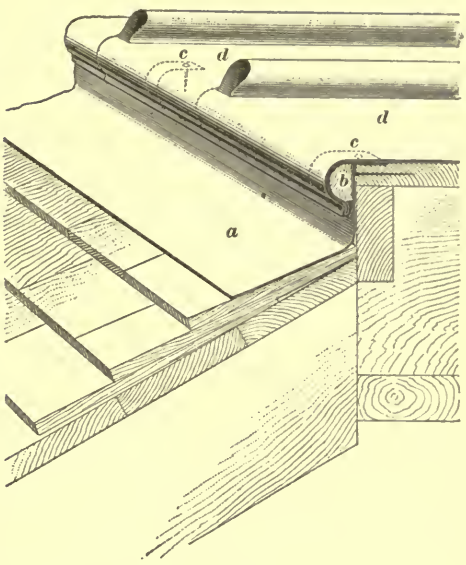


FIG. 81.

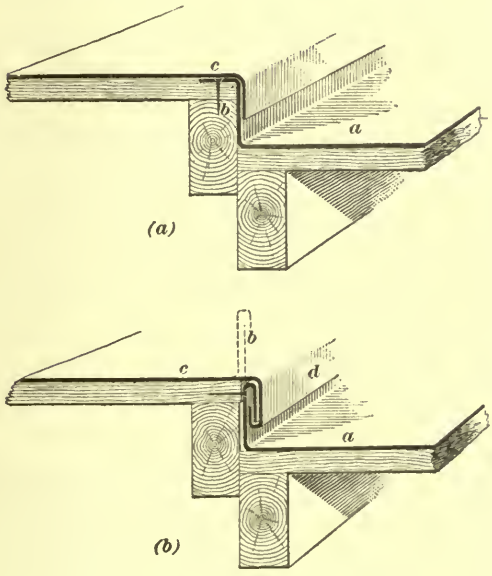


FIG. 82.

Drips are joints made across the current of the roof, and are located according to the length of the sheets used. They are constructed in two ways, as shown in Fig. 82 (*a*) and (*b*). In the *first* method, the sheet on the lower level *a* is bent up and over the step *b*, let into

a rebate cut for it in the boarding of the higher level, and is nailed securely. The upper sheet *c* is lapped over it and turned down. To avoid capillary action, there should be at least $\frac{3}{4}$ inch between the edge of this sheet and the sheet on the lower level.

In the *second* method (*b*) the lower sheet *a* is bent up, $1\frac{1}{2}$ inches above the upper level, as indicated by the dotted line *b*. Sheet *c* is bent up and over the edge of the lower one; the two sheets are then folded over and downwards, forming a lock *d*, as shown.

101. In covering small angular or curved surfaces of woodwork, it is necessary to screw the lead to the woodwork, to keep it in place. This is done as shown in Fig. 83. The boarding *a* is countersunk, and the lead *b* is formed into the cavity, and screwed in place with screws *c*, *c*. The cavity *e* in the lead is then filled with molten solder, to protect the screw heads and render it water-tight. The lead should be made to flow under the screw heads to prevent the sheet from tearing.

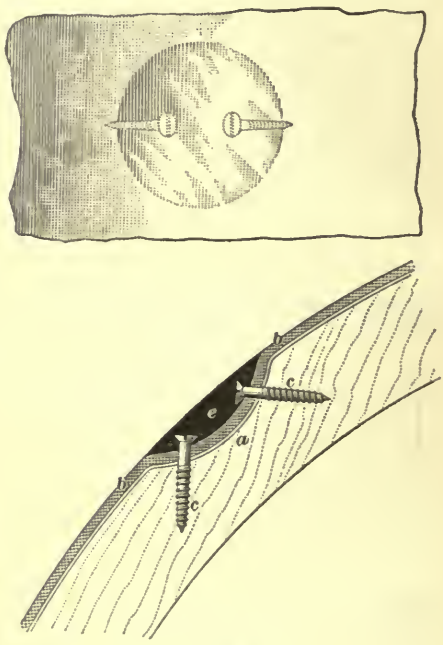


FIG. 83.

102. Lead flashings are constructed in nearly the same manner as other metal-roof flashings, the chief difference being the manner of securing the upper edge to the masonry or brickwork. As with other metal flashings, wall

hooks may be driven in the joint over the apron or counter-flashing. Plugging with lead is, however, preferable to all other methods. The plugs are about $1\frac{1}{4}$ in. $\times 2$ in., made to suit the joint in the masonry, or the raglet cut therein to receive the flashing. After the plugging, the joint or raglet must be pointed up with mastic or elastic cement. Burning in makes the most permanent joint. The flashing is inserted in the raglet, which is then filled with molten lead and calked in. This method is, in most cases, very difficult to execute properly, on account of the position of the joint. Unless the joint is in a very exposed location, the plugging will be sufficient.

103. *Lead gutters* should have a current or fall of at least $\frac{1}{4}$ inch to the foot, and the joints between the sheets

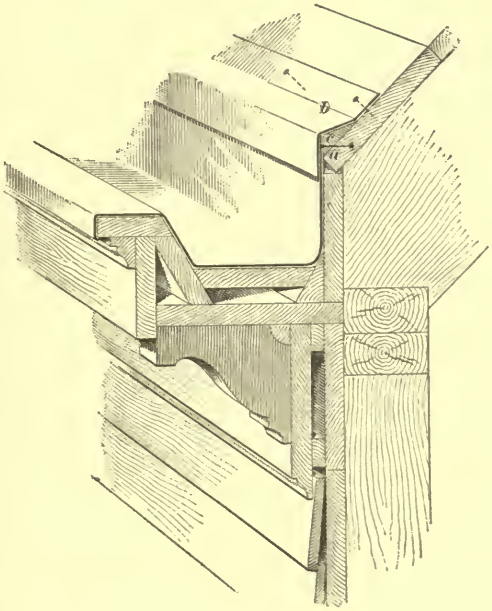


FIG. 84.

should be formed where possible with drips, the same as mentioned for flats. The sides of gutters abutting the

walls should be turned up 6 or 7 inches and counterflashed, the ends of the gutters being bossed, or folded up, and soldered.

Trough gutters should have the outside edge turned over the wood or stone crown member, and left without fastening. The inner side should be carried up at least 4 inches above the outer and over a tilting fillet on the roof, or otherwise stopped off at the board line. Where the gutter is not very wide, the counterflashing may be dispensed with, and the gutter lining, as shown in Fig. 84, may then be simply flanged over the tilting fillet and covered with a counterflashing *b* nailed over the tilting fillet *c* to the roof boards *a*. When a gutter comes against the back of a horizontal parapet wall, the wall should be pierced about 5 inches above the lowest part of the gutter, and an overflow should be provided to take off an occasional excessive fall of rain water, or an overflow caused by the leader being stopped at the eaves or drip. If the gutter is very long, there should be more than one outlet.

In working lead flashings around corners and in angles, great care should be taken to avoid sharp angles, otherwise the lead is likely to be cut.

104. The following weights of lead for the different parts of a roof are generally applicable: For flats and gutters, 6 to 8 pounds per square foot; for flashings, 5 pounds per square foot; for hips and ridges, 6 to 7 pounds per square foot.

Where the roofs are very much exposed, or where temperatures are extreme, heavier lead should be used.

105. For lead roofs or flats much worked over, a wooden-slat floor should be laid. In using lead for gutters with slate or tile roofing, the more the latter can cover and protect the lead from the sun, the longer the lead will endure. In using lead for apron or center flashing, on very steep gables, the stepped or skeleton-flashing method is to be preferred, as it keeps the lead in a horizontal position;

otherwise, the lead is apt to stretch and crawl until it becomes too thin to be of any value.

106. The thickness and the weight per superficial foot of lead used for roofing purposes are given in the following table:

TABLE 13.

Thickness. Inch.	Nearest Simple Fraction.	Weight. Pound per Square Foot.
.068	$\frac{1}{16}$	4
.085	$\frac{5}{64}$	5
.101	$\frac{3}{32}$	6
.118	$\frac{7}{64}$	7
.135	$\frac{1}{8}$	8
.152	$\frac{9}{64}$	9

SHEET-ZINC ROOFING.

107. **Zinc,** one of the useful metals, generally extracted from mountain limestone and magnesium limestone in conjunction with galena, is met with abundantly in the form of a sulphuret. The ore is roasted, mixed with charcoal, and heated in peculiar retorts. The zinc is converted into vapor, condensed, and fused.

Cast zinc is brittle when cold. Heated to 200°, it is ductile as well as malleable, and may be rolled into sheets retaining these properties at that temperature; while, if the temperature be allowed to exceed 400°, the zinc returns to its original condition of brittleness. When exposed to the air, at a high temperature, it will burn and be consumed.

Zinc is easily acted upon by moist air, but a film of oxide is soon formed, protecting the metal from further action. Its expansion and contraction are greater than that of any other metal. Zinc is nearly as durable as lead or copper, and is not as liable to be affected by the sun's heat. In its

metallic form, zinc is largely used for roofing and cornices, and also for galvanizing iron.

Good zinc should be free from iron, and zinc containing more than 1 per cent. of lead should be rejected, the lead making it brittle. Good sheet zinc is uniform in color, tough, and easily bent backwards and forwards without cracking. Inferior zinc is dark in color and of a blotchy appearance, caused by the presence of other metals. The conjunction of the dissimilar metals is liable to set up galvanic action, which soon destroys the zinc.

Zinc should not be secured by, or connected with, iron, copper, or lead, for, in either case, voltaic action is induced, which destroys the zinc.

108. Zinc is described by the weight and thickness of the sheets to the superficial foot. The gauges used for roofing run from 13 to 16. The weights of these gauges run from 1 pound to 1 pound 8 ounces per square foot.

The size of sheets varies from 24 to 52 inches wide by any length ordered. The ordinary length of sheet varies from 6 to 10 feet, but zinc may be obtained in long roll lengths.

109. Solder should never be used in zinc roofing except for the small vertical joints of flashings. Before soldering, the joints are fluxed with muriatic acid.

Paper or felt should always be used under zinc where it comes in contact with woodwork containing acids, as, for instance, oak; otherwise, these acids cause the zinc to corrode.

110. The methods employed in laying zinc roofing are hollow roll, wood roll, trough and cap, and standing seam. Where there is no boarding, corrugated roofing is generally employed; the corrugations give the plates strength. Soldered or rigid connections are to be particularly avoided, and the joints must be so arranged as to be weather-tight, but allowing free movement for expansion and contraction.

Hollow-roll zinc roofing is constructed in the same manner as with copper, as shown in Fig. 63.

Wood Roll.—Same as copper roofing, Fig. 65.

Trough and Cap.—This method is much the same as that

used for copper, the difference being that the cap *a* is slipped over the lock *b* of the trough, as in Fig. 85, clips not being required to keep it in place. The flat portions of the roof are secured with clips at the head of each sheet, made to fit into the lock seam, the clips being nailed to the roof boards. The sides of the sheets are secured by the locking or seaming over them of the edges of the trough *b*. The ends of the rolls should be closed or stopped by turning down a portion of the roll cap *a* against the wood roll, and by folding the corners of the sides of the cap *b* and trough *c* under this end. See Fig. 86.

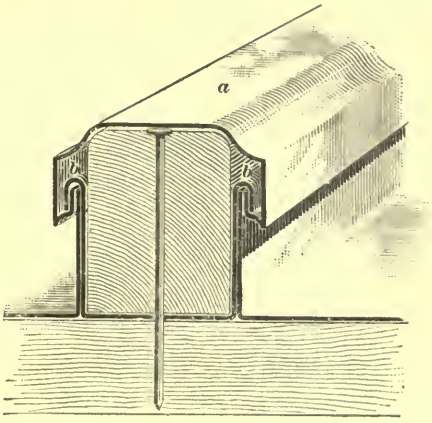


FIG. 85.

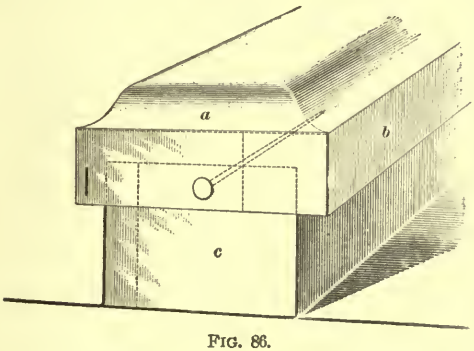


FIG. 86.

If the roof is very flat, drips should be used at the end of each sheet, as described and shown for lead roofing in Fig. 82. The lower edge of the sheets, next to the eaves, should be strengthened by turning or doubling it back so as to form a bead, or by locking it to the gutter edge, where it joins the roof.

Standing Seam.—Same as described and shown for tin roofing. See Fig. 49.

Corrugated zinc is laid with the flutes running up and down the incline. The sheets overlap to the extent of one

corrugation at the sides, and 4 inches at the ends where connections are made. This method is shown under galvanized-iron roofing.

Ridge caps or rolls should have the edges *a*, Fig. 87, turned up and under, to make a strong edge, and should be secured in place by slipping the edge over the clips *b*, which are placed at intervals of 15 inches and nailed to the ridge. The cross-seams, where the lengths of the caps meet, are closed with a single lock seam.

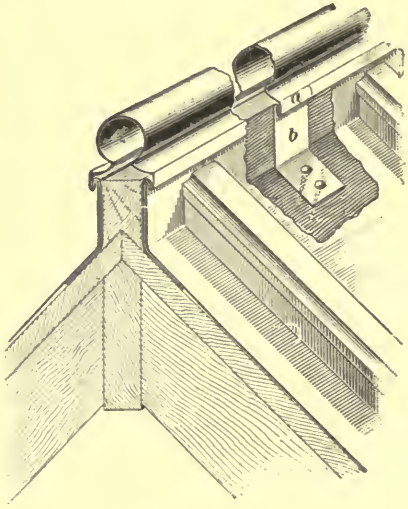


FIG. 87.

Flashings for Chimneys, etc.—The same as for other metal roofs, save that no other metal but zinc should be used, on account of the great difference in the expansion and contraction.

111. The gauge, thickness, and weight per superficial foot of zinc used for roofing purposes, are given in the following table:

TABLE 14.

Gauge Number.	Thickness. Inches.	Weight. Ounces per Square Foot.
13	.0311	10
14	.0457	12
15	.0534	14
16	.0611	16
17	.0686	18
18	.0761	20

SLATE ROOFING.

PROPERTIES OF SLATE.

112. **Slate** used for roofing purposes, commonly known as *clay slate*, is obtained from an argillaceous or clayey rock, of a compact and fine-grained texture. This rock is formed through the deposition of matter by the action of water, and belongs to a class geologically termed *sedimentary* rock, which split very readily into thin laminæ or slabs, along parallel planes, called the cleavage planes—a characteristic that renders slate very valuable as a roofing material.

The cleavage planes do not run in any fixed direction with respect to the beds, but incline at various angles, from perpendicular to horizontal. The slate whose cleavage planes are most nearly horizontal or parallel to the natural bed, is unfit as a roofing material, as the slabs will have a rough and irregular surface, which will prevent them from being fitted closely when laid.

113. Good slate should possess both toughness and hardness, and a very fine, but easily distinguished grain. The slates should be tough enough to be easily punched for nailing, and should cut to standard sizes, without splintering or becoming friable at the edges; and they should be hard enough not to absorb much moisture, as the action of frost upon the moisture will cause the edges to crumble and will also tend to enlarge the nail holes, and thus cause the slate to loosen from the roof.

The *grain* should run lengthwise of the slate. Veins or ribbons are objectionable markings, especially when parallel with the grain. Crystals of pyrites are sometimes found in slate, the yellow variety of which is not very injurious, but still objectionable, except in those qualities classed as second rate. Slate containing white pyrites, however, should always be rejected. The *color* of slate varies considerably, and is in no way indicative of the quality of the material. Blue, blue-black, purple, gray, green, and red are the

commonest tints, though cream color is occasionally but rarely found.

114. Qualities of slate vary with the characteristics of the rock, as above described, as do also the straightness, smoothness of surface, and uniformity of thickness of the quarried product. All qualities are obtainable in various market sizes from 6 in. × 12 in. to 24 in. × 44 in., all $\frac{1}{8}$ to $\frac{1}{4}$ in. thick, the common average being $\frac{3}{16}$ in. Tests to determine the quality of slate are sometimes made, but cannot be relied upon, though they are of value in some instances where certain characteristics are to be determined.

The *porosity* and amount of absorption may be obtained by weighing a dry slate, as delivered from the quarry, and reweighing it after soaking for 24 or 36 hours in water; the difference in weight shows the amount of water absorbed. Or a slate may be permitted to stand on edge, in a shallow dish of water, the height to which the water rises in the pores being noted; if the absorption is great, the slate is not suited for roofing, as the frost would tend to splinter the edges.

Slate submitted to the action of dilute sulphuric acid, will, if of a proper degree of hardness, remain unchanged for several weeks, but if of soft quality, it will decompose and crumble in a few days. Powdered slate, submitted to the action of muriatic acid, will effervesce strongly when it contains carbonate of lime, and should not then be used for roofing purposes. Powdered slate submitted to a high temperature, will give off a yellow sublimate of sulphur, when it contains pyrites, and should not be used, as it is not of a durable quality.

Though the above tests tend to show some of the characteristics of different qualities of slate, they are not entirely reliable as determining the value of the slate as a roof covering, as some of the hardest slates will undergo decomposition on the roof, even after passing all of these preliminary tests.

A good slate should present a bright, silk-like luster, and

should emit a clear metallic ring when struck with the knuckles, showing that it is hard; if it is soft, it will have a dull lead-like surface, and will give out a muffled sound. When cut, the edges should show a fibrous-like texture, free from splinters, and the material should not show signs of being either brittle or crumbly.

No better test of the wearing or weathering qualities can be contrived than the simple and effective one of examining roofs where the slate has been in service for several years.

LAYING SLATE ROOFING.

115. Terms Used in Slating.—The terms applied to the different parts of roofing slate are: the *gauge*, or *weather*, which is that part of the slate which is exposed when laid, as shown at *a*, Fig. 88; the *lap*, which is the distance that each slate overlaps the second one below it; the *head*, or upper end of each slate, as at *c*; and the *tail*, or lower end of each slate, as at *d*. The *bed* is the under surface of each slate when laid. The *back* is the upper surface when laid.

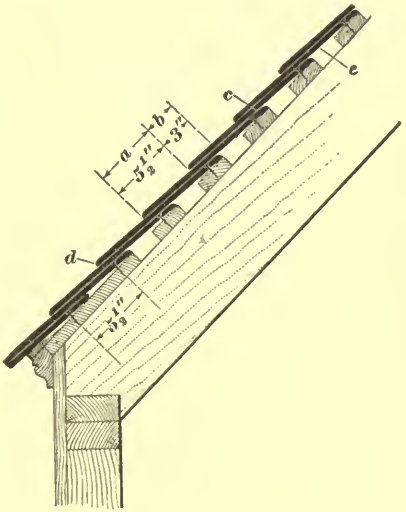


FIG. 88.

Rendering consists in covering the under side of the slate with haired mortar, especially when the slates are laid on battens, though it is sometimes done when the roof is boarded, by laying the slate on the mortar, which has been applied directly to the boards. Rendering prevents the wind from blowing the rain or snow through the crevices when felt is not used over the boards. It is not effective when the slate is laid on

lath or battens, as they are likely to settle and crack the rendering.

Shouldering consists in applying to the head of each slate, to a depth of 2 inches, a thin bed of haired mortar or slater's cement. Shouldering is resorted to only in very exposed situations.

Torching consists in pointing the joints between the heads and tails of the slates from the under side with haired mortar or slater's cement, and is done after the slates are laid; it is of little value, as it soon falls out, leaving the joints open.

116. Nailing.—There are two methods of nailing slate: *head* nailing and *shoulder* nailing. In head nailing, which is the usual method employed, the nail holes are punched about two inches from the top, as at *a*, Fig. 89, and the tails

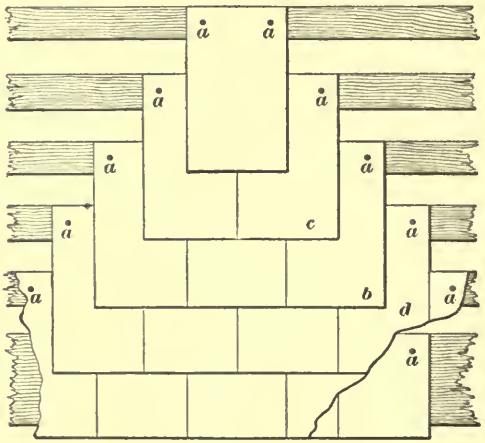


FIG. 89.

of the next two courses, as *b* and *c*, lap over the nail holes. Should the first-covering slate *b* become broken, the nails are thus still protected from the weather by the lap of the second-covering slate. The objection to this method is the leverage exerted by the wind. In shoulder nailing, Fig. 90, holes are punched at a distance from the tail of the slate equal to a little more than the gauge plus the lap.

117. The tail ends of slates are sometimes cut on the corners so as to give, when laid, a semi-octagonal or triangular gauge, and when so treated are termed *cut* slates.

Cut slates tend to shed the water more rapidly than square-end slates, as their form acts as a guide, carrying the water to a point, which it readily leaves, thereby clearing the roof

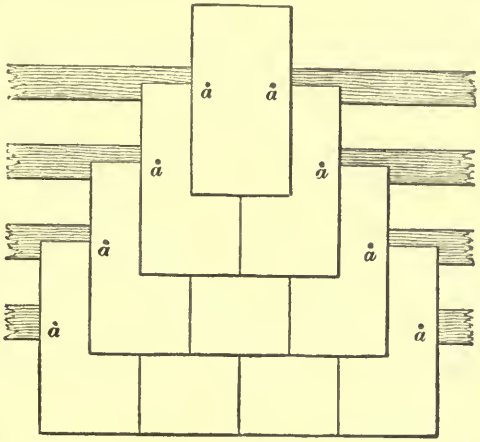


FIG. 90.

quickly; while, with square slate, the water lodges in the joints and accumulates on the lower edge and drips off so slowly that the joints are wet when the rest of the roof is dry. In winter, the alternate freezing and thawing is likely to loosen the slate and cause the edges to crumble. A roof covered with cut slate is, however, not so strong, as so much of the material is cut away.

118. Sorting and piling slate preparatory to laying is a most important detail of the roofer's work. Slates should be piled with their edges up, the pile in no case being more than 3 feet 6 inches in height; the ends of the tiers may be held up by laying a pile of slates on the flat, while the top of the pile should be covered with slate laid flat, with broken points, so as to keep out moisture. The slate should be sorted or selected by grades of thickness, the thin slate being piled first and the thicker ones next; or, if there are three grades, the medium thickness should be piled before the thickest.

The thick slate should be punched first, then the thinner ones, as the thick slate should be laid on the lower part of the roof and should be taken up first.

119. *Machine-punched* slate make a better job than *hand-punched*. In Fig. 91 is shown a section through a machine-punched slate; the hole is clean cut and gives the very best result.

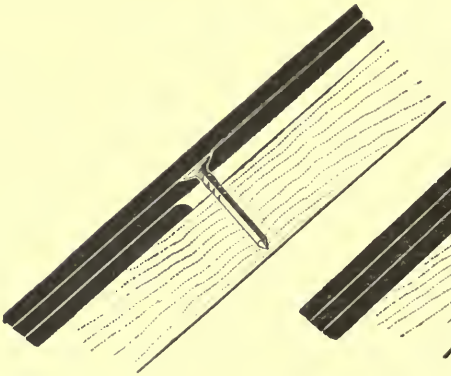


FIG. 91.

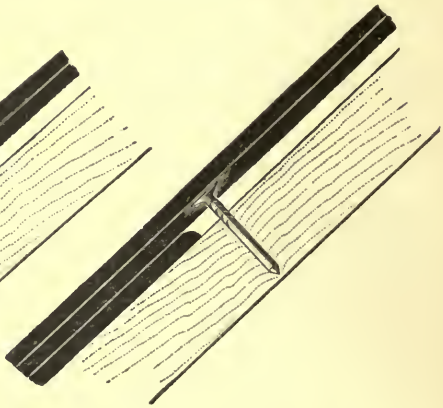


FIG. 92.

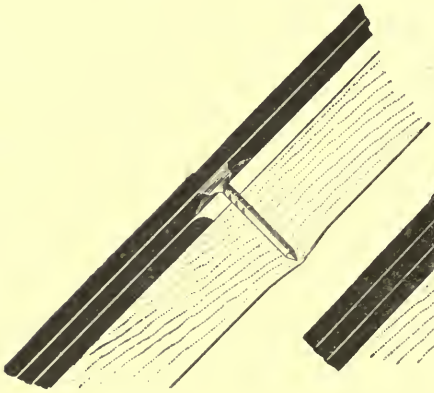


FIG. 93.

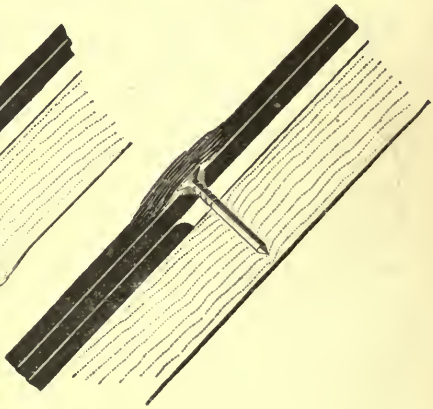


FIG. 94.

In Fig. 92 is shown a hand-punched slate whose edge is ragged and flaked, the slate consequently being weakened. In Fig. 93 is shown another machine-punched slate, but with the nails driven too tight. The result is as indicated. The

slate having sprung to its natural position, the under side is splintered and the value of the nailing is lost. In Fig. 94 is shown a machine-punched slate with the nail insufficiently driven, causing the nail head to be forced through the upper slate by pressure from above.

120. There are three methods of laying slate roofing: (1) on laths or battens; (2) on boards covered with felt; and, (3) a method called half slating, on either battens or boards.

With the *first* method, of lath or battens, the roof is prepared as for shingles laid on lath, as previously explained.

For the *second* method, where the slates are laid on boards, the best results are obtained by covering the roof with $1\frac{1}{4}'' \times 6''$ matched boards. The objection to wider sheathing boards is that they are likely to shrink, curl on the edges, and lift some of the slates, thereby giving the roof a rough, uneven appearance. If wide boards are used, however, they must be well nailed at both edges. More care in this respect is needed when the sheathing is applied to curved roofs, or round towers, in which cases the sheathing must be perfectly solid and smooth. When the sheathing is not solid, the driving of a nail is almost sure to loosen the slate which was previously nailed, and a uniformly tight job is impossible.

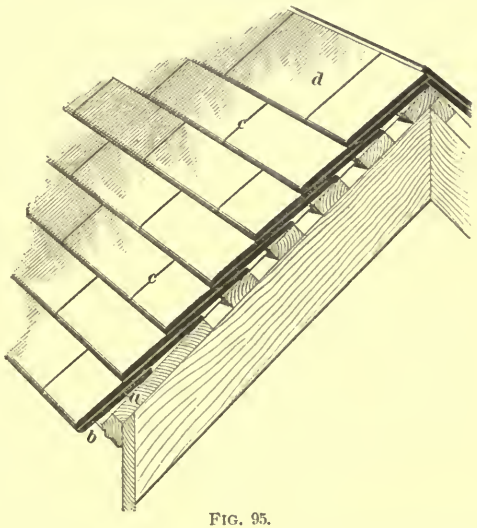


FIG. 95.

The sheathing felt should be applied parallel to the eaves, if possible, but if the roof is steep it may be laid at right angles to them. In either case it must be lapped 2 inches

and fastened to the roof with nails having large flat heads. The tilting fillet at the eaves, valleys, gable ends, etc., the saddles and cant boards at the back of chimneys, flashings, etc., as previously described, should all be well secured to the roof boards.

In commencing to slate, the first course is laid double, the lower, or "undereaves" course being laid with the back of the slate next the boards; the length of the slates in this course will be equal to the gauge plus the lap, as seen at *a*, Fig. 95, and should project over the eaves or gutter edge from $1\frac{1}{2}$ to 2 inches, as at *b*. All the courses must be laid with broken joints, as shown at *c*, up to the ridge; the last course, as at *d*, is known as a "finisher," and is put on to receive the ridge roll.

121. The *third* method, known as *half slating*, is generally used on cheap buildings, where great economy of material is required. If laid on battens, half-slating should be used only where a perfectly tight roof is not necessary; but if laid on boards covered with felt, it makes a good serviceable low-priced roof. The lower courses should be laid double, as in the other methods. The courses above this have a space between the edges of the slates equal to one-half the width of each slate. The whole surface is thus laid, up to the ridge, the last course, or finisher, and the ridge roll being completed as for the other roofs.

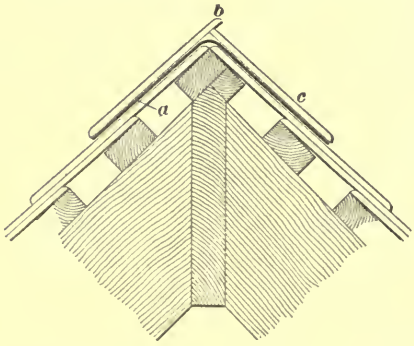


FIG. 96.

122. The *ridge* on a slate roof may be finished in various ways. A method used on cheap buildings has a metal saddle flashing, as at *a*, Fig. 96, with the slate finished over it, one slate lapping over the other $\frac{1}{2}$ inch, as at *b*. The wings of

the metal flashing are just equal to the length of the ridge slate *c*. The objection to this form is that the nails securing the ridge slates are driven through the metal flashing.

Another method consists in nailing to the roof boards a wooden ridge saddle or strip *a*, Fig. 97, on each side of the

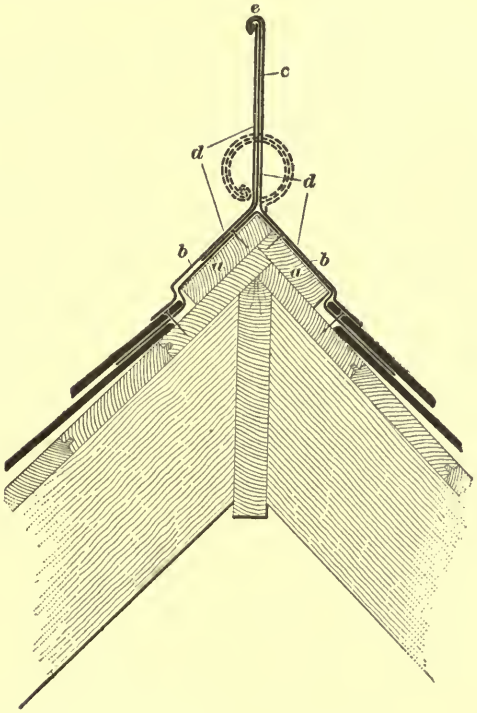


FIG. 97.

ridge. A saddle flashing *b* is then bent over this, with the wings extending 4 or 5 inches down the roof and under the last course of slates, which are laid up to the edge of the saddle *a*. Strips of metal *c*, 8 in. or 10 in. × 2 in., are nailed along the saddle at intervals of 16 inches, and a wing piece *d* is then laid on each side, lapping over the slate 2 or 3 inches, and is bent and shaped up to the top of the clip *c*, over which it is turned and locked, as shown at *e*. The whole is then bent and formed into a roll, as indicated by the dotted lines.

A third method, much the same in principle, is shown in Fig. 98. The metal saddle flashing over the wood saddle is omitted, and the slate is carried up to the wood saddle, on which is nailed a wood roll, as shown at *a*. A wing flashing *b* is placed each side, overlapping the slate 2 or 3 inches, and is bent up against the roll and lock seamed as at *c*, with its upper edge against the side of the roll; this flashing is then secured by nailing under the lock seam into the wood roll. A metal roll cap *d* with lock-seam edges, slipped over the wood roll, interlocking with the edges of the wings, completes the ridge. A cheaper roll is constructed as shown in Fig. 99, the roll *a* being kept in place by its natural spring.

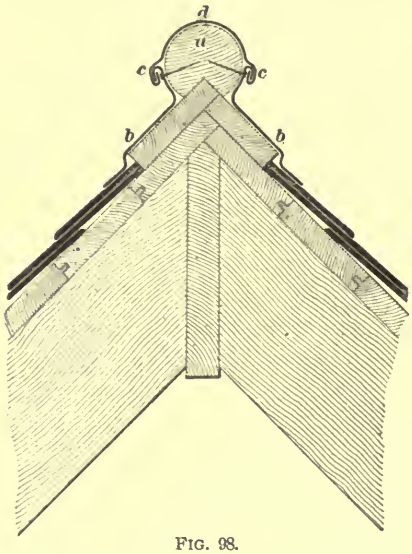


FIG. 98.

Methods of capping with slate rolls and wings are seldom used on account of their expense, but when necessary should be constructed as shown at (*a*) and (*b*), Fig. 100.

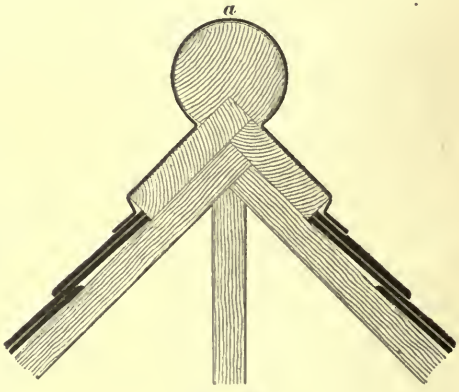


FIG. 99.

At (*a*) the wing pieces *a* are cut from solid slate; they are screwed together with brass screws *b*, and the cap *c* is placed

over them. At (*b*) the wing piece *a* has the roll cut on it and laps the wing *b* on the other side. Both ridges must be set in cement, without nailing to the roof.

A good rule to follow for proportioning the wings to the roll is: with a 2-inch roll use a $5\frac{1}{2}$-inch wing; with a $2\frac{1}{2}$-inch roll use a 6-inch wing; and with a 3-inch roll use a 7-inch wing.

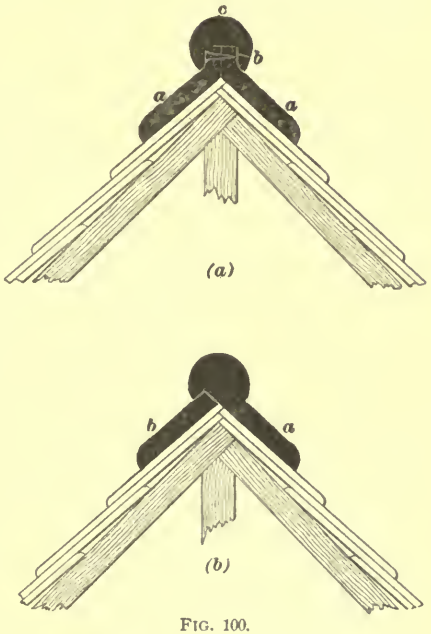


FIG. 100.

123. Hips and Valleys.—Hips in slate should be finished the same as described for shingle roofs. If a roll is applied, the simple method shown at Fig. 99, with a short flat wing, will serve all purposes and will give a neat finish.

Valleys may be constructed in the same manner as those described for shingle roofs, as may also the flashings around the chimneys, skylights, bulkheads, ventilators, etc.

Where a slate roof finishes against a parapet, gable, or other wall of brick or stone, there should be provided both flashings and counterflashings, the flashings to be cut in short lengths, 2 inches longer than the unexposed part of the slate, and to be laid as each course of slate is put on, as shown at *a*, Fig. 101. This flashing should have a lap on the roof equal to the width of half a slate, and should turn up against the wall at least 4 or 5 inches. The flashing against the wall must not then be nailed, for if the roof settles, the flashing will lift the slate or break them. This flashing is sometimes called a "soaker." The counterflashing

b, which covers the soaker flashing, is either let into a raglet cut 1 inch deep in the stone or stepped into the joints, as shown. This stepped counterflashing is secured at the top

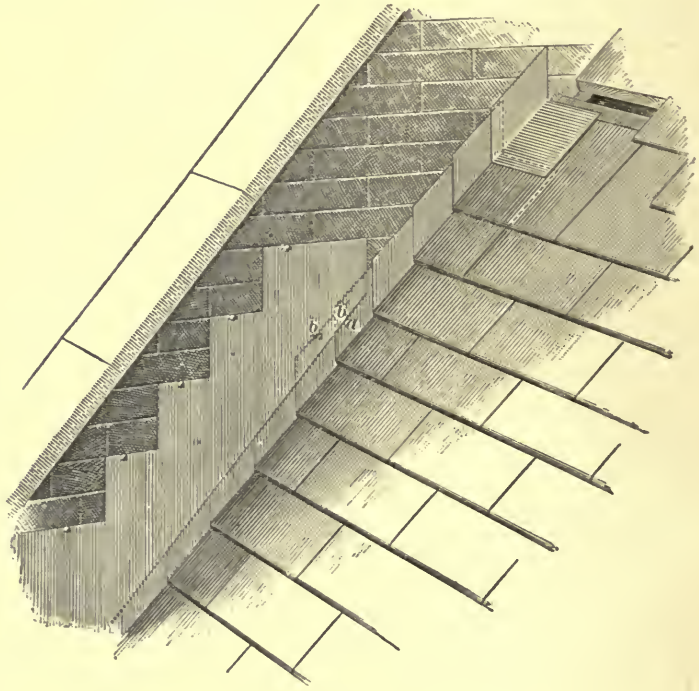


FIG. 101.

by wall hooks, and the joints are well pointed up with elastic cement.

When lead is used for flashing instead of tin, zinc, or copper, it should not weigh over 5 or 6 pounds to the square foot, as the thickness will give an uneven appearance to the slate.

124. Colored or ornamental slate should be used with great care, as color never increases the utility of the roof and is more likely to spoil an otherwise respectable roof by a poor and gaudy design, while the cutting of the slate

to any shape that tends to carry away the water from the joints, as before described, is the only recommendation for ornamental forms. Colored slate is necessary for certain buildings, but the color should be uniform.

In slating curved surfaces, follow the directions given for shingle roofs, commencing at the lower course, with slate from 6 to 10 inches wide, and gradually taking off until a slate 2 inches in width is reached. This is about the limit that will safely cover a nail hole and keep the weather from affecting it; even with this width the upper courses should be well bedded in slater's cement (which is generally composed of paint skins and refuse lead), as should also all hips, ridges, and joints around chimneys, bulkheads, gables, and parapet walls.

125. The nails used for slating have large, flat heads, so that they may get a good hold on the surface of the slate. The proper length of a nail is twice the thickness of the slate, plus the thickness of the boarding or lathing; this length will give the full amount of hold that can be secured. The nails generally used are threepenny, which are $1\frac{1}{8}$ inches long, and fourpenny, which are $1\frac{3}{8}$ inches long.

WEIGHT OF SLATE PER SQUARE FOOT.

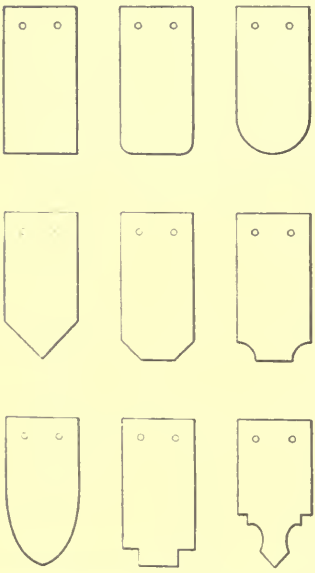
Thickness. Inches.	Weight. Pounds.
$\frac{1}{8}$	1.82
$\frac{3}{16}$	2.73
$\frac{1}{4}$	3.64
$\frac{3}{8}$	5.46
$\frac{1}{2}$	7.28
$\frac{5}{8}$	9.06
$\frac{3}{4}$	10.87
1	14.50

126. Slating is calculated by the square of 100 square feet. To ascertain the number of slates of a given size required per square, subtract 3 inches from the length of the slate, multiply the remainder by the width and divide by 2; this will be the number of square inches of roof covered by the gauge of each slate. Then divide 14,400, the number of square inches in a square, by the number of square inches covered by each slate, and the result will be the number of slates required for a "square" of roof.

TILES.

127. The clay used in the manufacture of tiles is composed of aluminum and silicic acid, forming two-thirds of its bulk, with about 10 per cent. each of water and quartz, and very small quantities of potash, titanic acid, and oxide of iron. To prepare the clay for use, it is weathered, which means exposing it to the frost or sun, then mellowed or allowed to stand for a period, tempered by additional working of the clay, plugged, and cleared from stones. It is then ready for molding, after which it is burned in a kiln, glazed, and fired.

128. *Salt-glazed, vitrified* tile are subjected to intense heat, the glazing being accomplished by throwing salt on the tile in the fire, creating a vapor which unites chemically with the clay and forms a glazing which is affected by neither gases, acids, nor steam, and is practically indestructible. *Slip-glazed* tile are what are known as firebrick clay tile; they are very porous, and are glazed with another clay known as slip, which is applied under heat; the slip, however, being a foreign body is liable to chip and scale off. For this reason, vitrified tile should always be used in preference to the slip glazed.



Tiles of good quality emit a clear ringing sound when struck together, or with a steel tool. The gauge of tile is the same as of shingles, and refers to the exposed portion of the tile.

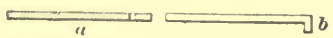


FIG. 102.

129. The styles of tile manufactured are very

numerous; they are, however, generally of the interlocking pattern, and made so that they may be laid either on boarding or on battens. The following varieties are generally used: the plain surface tile, with the eave hips; ridge or cresting tile; and finial to suit. Shingle tile are called *square*, *round corner*, *round end*, *hexagon*, *octagon*, *scallop*, *Gothic*, *Grecian*, and *Persian*, and are shown in the order named in Fig. 102. Those used for laying on boards are flat, as at *a*, with two nail holes in the upper end, and those for hanging on lath have the rib or lug *b* cast on the back, as well as having the nail holes. The French tile

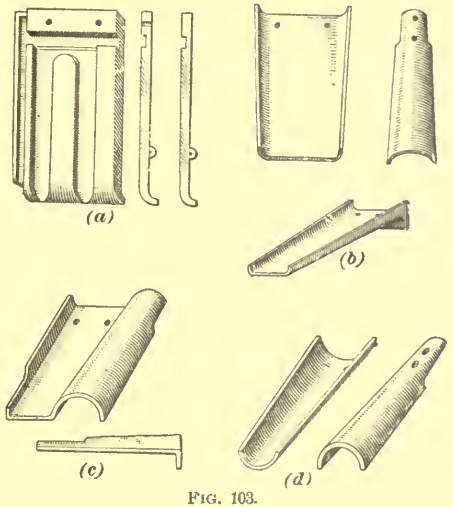


FIG. 103.

shown in Fig. 103 (*a*) may be used for laying on boards or battens; the Roman, Fig. 103 (*b*), for boards or battens. The modern Spanish tile is shown at (*c*), and the old Spanish, at (*d*), Fig. 103.

In Fig. 104 (*a*) is shown the Corean or Oriental ridge tile to be used with modern Spanish tile shown at (*b*); the eaves or starter tile is shown at (*c*). Ridge tile should be special, and when so made, the wing of the ridge takes the form of the tile at its lower edge. Eaves tile may be made with

antefixas, as shown at (*d*), Fig. 104, which enrich the appearance of the eaves and take the place of the plain finish.

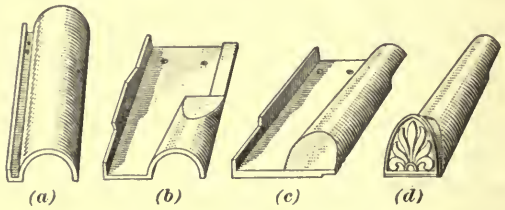


FIG. 104.

These tiles are sometimes inserted at intervals on the roof to act as a snow guard. *Hip-roll* tile [see Fig. 105, (*a*), (*b*), and (*c*)] are overlapped 3 inches when laid, while the roll tiles shown at (*d*) and (*e*) have lap joints cast on them; these tiles are secured to the wood hip roll by nails at the lap.

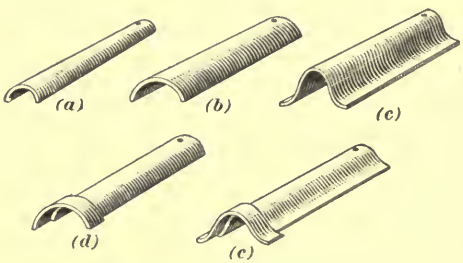


FIG. 105.

Plain overlapping cresting, or ridging, is shown at *a*, Fig. 106, and consists of rolls and covers with a plain cresting

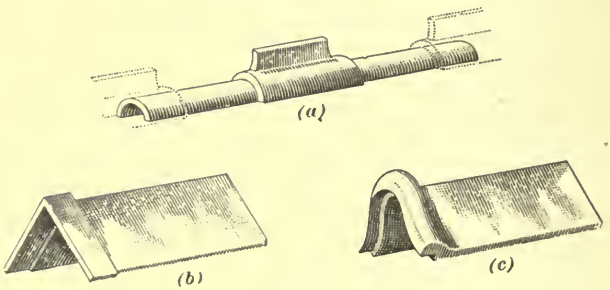


FIG. 106.

cast on the cover tile. At (*b*) and (*c*), Fig. 106, are shown two styles of lap-joint ridge cresting.

At (*a*), Fig. 107, is shown a ridge roll made to receive the

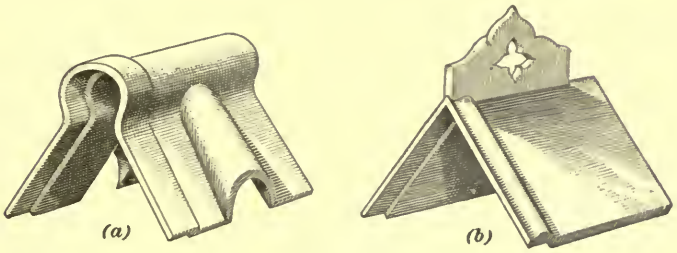


FIG. 107.

tile and also having a lap joint, and at (*b*), an ornamental ridge cresting with lap joint.

At (*a*) and (*b*), Fig. 108, are shown two styles of gable finials. At (*c*) and (*d*) are shown two hip finials—one with

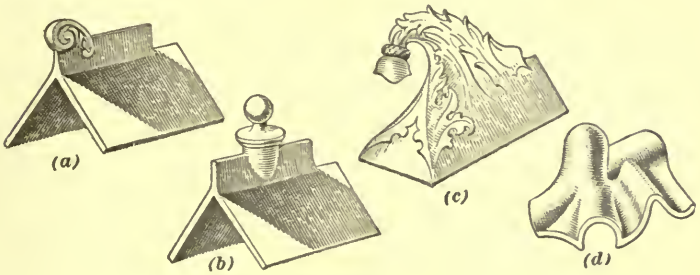


FIG. 108.

plain wings and the other with wings made to receive the hip-roll tile, the center tile of the front slope, and the first continuous row of tile of the side pitches.

130. The thickness as well as the length and breadth of tile varies; they run from $\frac{3}{8}$ to $\frac{3}{4}$ inch in thickness, from 3 to 9 inches in breadth, and from 10 to 16 inches in length; the $\frac{3}{8}$-inch thickness is generally used.

131. There are four methods of securing tiles to the boards or battens: (1) by hanging with oak pegs as shown in Fig. 109 (*a*); (2) by nails as at (*b*); (3) with a rib or lug

and nails as at (*c*); and, (4) as shown at (*d*), with a rib or lug and also by a wire loop, which is nailed to the lath or batten.

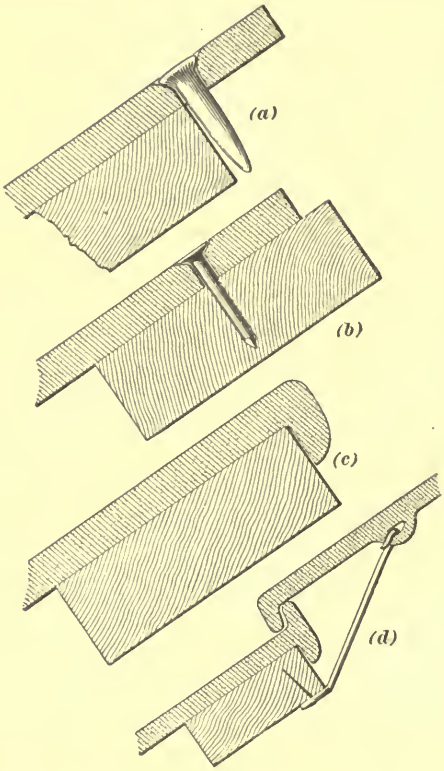


FIG. 109.

Rendering is used with flat tiles, and torching and shouldering with all tiles in very exposed places, or on flat-pitched roofs; under ordinary conditions, however, these processes are not necessary. When used, they should be applied in the same manner as described for slate roofing.

The roof should be prepared to receive the tile by covering the rafters with either boards or battens, as the kind of tile to be used requires. If boards are to be used, sheath with plank $1\frac{1}{4}$ to $1\frac{1}{2}$ inches thick and 6 or 8 inches wide, tongued and grooved, and laid on diagonally, well nailed at each bearing and at the edges to prevent curling.

Tilting fillets should be nailed at the eaves, valleys, gutters, gables, etc., as described for shingle roofing. When battens or lath are used, especial care must be taken to see that the proper distance is secured between the lath for the tile to be used, and that the lath are horizontal to the eaves, so that the vertical joint of the tile will be at right angles to the eaves. If the tiles are laid on boards, the roof should be covered with two thicknesses of single-ply or one thickness

of double-ply fibrous roofing felt, and after the felt has been applied, the gutter and other flashings should be constructed —as described under "Shingle Roofing"—and put in place.

132. The gutter flashing should be of 16-ounce copper, well nailed with copper nails over the eaves tilting fillet, and locked to the gutter proper with a lock seam unsoldered; or it may be turned down over the upstand of the gutter. The first method is used for a gutter nearly level with the eaves, and the second when the gutter is slightly below the eaves.

For valley gutters, 10-ounce copper can be used in 6-foot lengths. It should be laid with a lock seam, fastened to the roof boards with cleats, soldered and sweated on the back of each length, and nailed with copper nails to the roof back of the valley tilting fillets, or screwed down with copper screws. The valleys should be 20 or 24 inches wide.

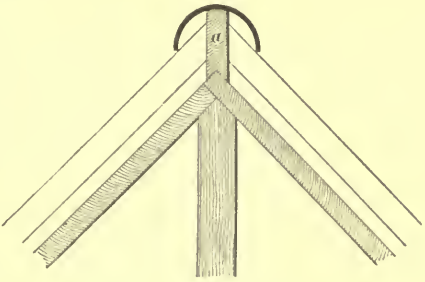


FIG. 110.

The hips do not require to be flashed. A wooden hip fillet as at *a*, Fig. 110, of sufficient height to receive the tile and give it bearing, is attached to the sheathing, and to this fillet the hip tile is secured.

Where a roof comes against parapet, or gable walls, the junction should be flashed with 14 or 16 ounce copper, nailed to the roof back of the tilting fillet. The flashing should be allowed to lap on the roof a distance equal to the width of a tile over the fillet, and should be carried up against the wall at least 7 inches. From the under side of the wall coping, or from a raglet cut in the wall, a lead apron should overlap the copper upstand at least 3 inches, and should be secured to the wall with lead plugs.

133. The ridge does not require flashing, but should be prepared to receive the tile ridge roll in the same manner as was shown for the hips.

Where the tile come against the wood hip roll, they should be cut off to the proper angle and bedded in elastic cement. The valley tile should be made at the works, to conform with the proper angle of the roof, and should have closed ends. Around all chimneys and other openings in the roof, as well as at the finishing course along the ridge, the tile should be well bedded in slater's cement.

Where the ridge tiles have a very deep wing, they should be specially cast with a lap joint, and should be laid in courses the same as the tile. See (*a*), Fig. 111. They are

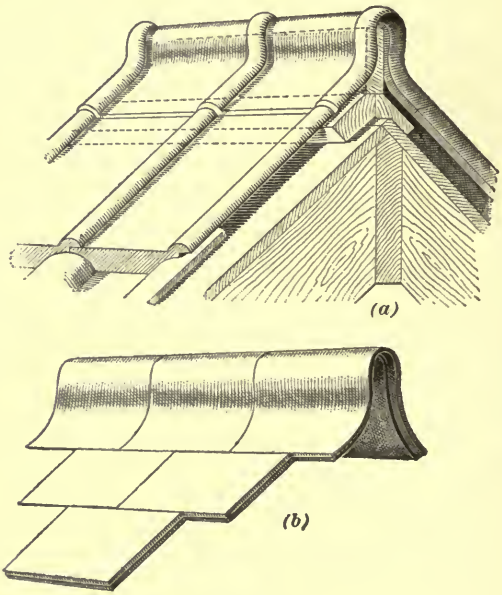


FIG. 111.

sometimes built up of flat pieces of tile, as at (*b*), Fig. 111, with rabbeted joints, and laid with the vertical joints broken; the former tile is preferable.

Very heavy hip or gable finials should be well braced with brass or galvanized-iron rods, and the sections of terra-cotta finials should be securely wired or anchored to the braces, and well cemented. If necessary, a wood cradle should be built on the roof to receive the finials.

The finials on hips and ridge ends may be secured with a tripod form of brace. For a vertical finial the tripod may be made and secured to the roof as shown in Fig. 112, the ends of the iron being held in place with brass or galvanized-iron screws. For an overhanging hip finial the brace may

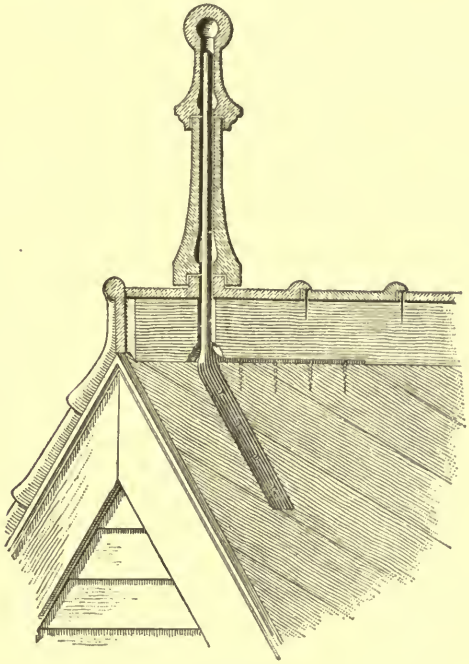


FIG. 112.

be constructed as in Fig. 113, the top of the rod being carried to the ridge of the finial. Where the finial is on the apex of a tower, the brace may be constructed with a galvanized-iron pipe of dimensions to suit the size and shape of the finial, and stiff enough to resist the wind pressure. The construction of such a brace is shown in Fig. 114.

134. A roof may be covered entirely with ornamental roofing tile, or they may be used at intervals among flat tile

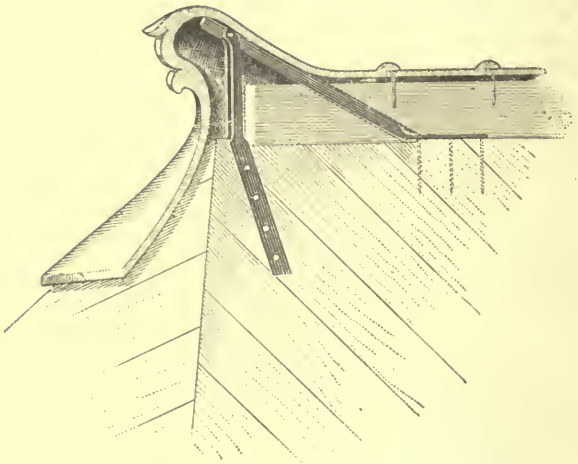


FIG. 113.

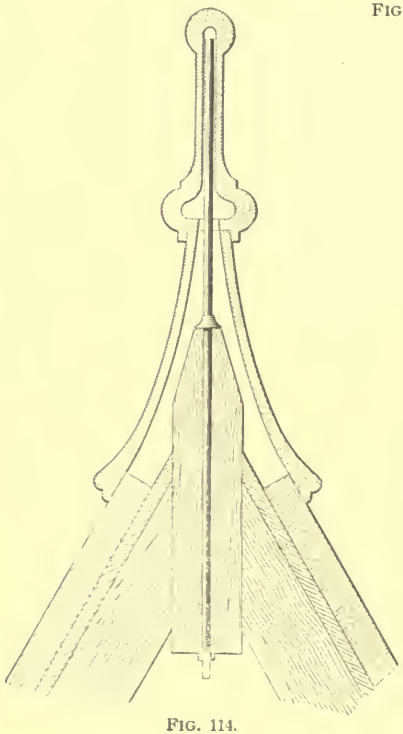


FIG. 114.

to break the monotony of the system. When mixed with the plain tile, they may be arranged in pattern or figure shape, but care must be taken to retain uniformity of color in both kinds, as mentioned in "Slate Roofing."

135. The tiles for conical roofs must be made to suit the requirements of each case. It is, however possible, with some varieties of tile, to use a uniform size for four or five courses, or tiers, and a smaller one for the next four or five courses, and so on until the base of the finial is reached.

Shingle tile may be cut on the sides so as to make them conform with the radial lines from the apex, in the same manner as was described for slate and shingles. If, however, the butt of the tile is formed with a pattern, this method cannot be used, and special tile must be made. The eave tiles and the upper courses adjacent to the apex should be well bedded in slater's cement.

GLASS ROOFS.

136. Glass as a roof covering may be used to great advantage for inside halls and passageways, picture galleries, and extensions where ordinary windows cannot be inserted, for dome lights, greenhouses, railroad stations, etc. Wherever used, the construction should be what is known as "puttyless," that is, no putty should be used in bedding the glass whether the bars are of metal or of wood.

137. The frame for all house work except greenhouses, and even the better class of these, should be, preferably, of copper, galvanized iron, or zinc.

The construction of these frames or bars consists of a gutter composed of three pieces, the *flange*, the *gutter*, and the *cap*. In Fig. 115 is shown the general construction of

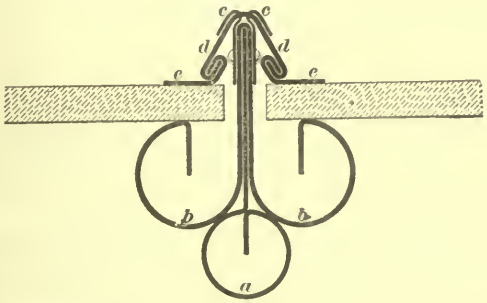


FIG. 115.

the complete bar. The center member *a* has a straight web about $1\frac{1}{4}$ inches high, with a circular tube $\frac{5}{8}$ inch diameter

formed at its lower edge. The gutter or outer member *b* consists of one piece, bent at the center, capped over the web or centerpiece, and having the edges formed into $\frac{3}{4}$-inch tubes which rest on the tube of the web member. The upper flanges of these tubes support the glass. The cleats or holdfasts *c*, which bind the cap, are secured by the rivets which join the web and gutter members, and the cap *d* is made of one piece, in the shape of an inverted **V**, with a simple lock on the two lower edges to receive the flashings. The flashings *e* are strips of lead, locked at the upper edge into the cap, and bent down close to the glass, in order to make a water-tight connection. The cap is secured to the bar by passing the clips through a slit cut in its apex, the ends being turned down and soldered and wiped to the cap. In some cases, the ends are simply turned down over the cap.

This system of construction may be applied to the whole or a part of a roof, and also to skylights. It may also be used in conjunction with iron or wood framing for the roof proper.

For small skylights, where an under support may be dispensed with, the light bar, as shown in Fig. 115, may be used. For larger openings, a heavy iron bar incased with sheet metal, as shown in Fig. 116, will give the requisite strength.

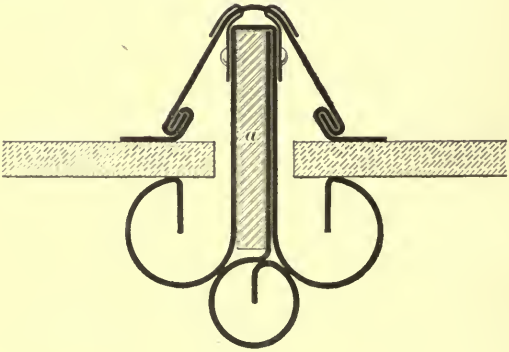


FIG. 116.

Fig. 117 shows an iron rafter for a roof; it is composed of a

web plate *a*, $3\frac{1}{2}$ in. $\times \frac{1}{4}$ in., and two angles *b*, *b*, 2 in. $\times$ 2 in. $\times \frac{1}{4}$ in. bolted together. The portion *a* projects beyond the flanges

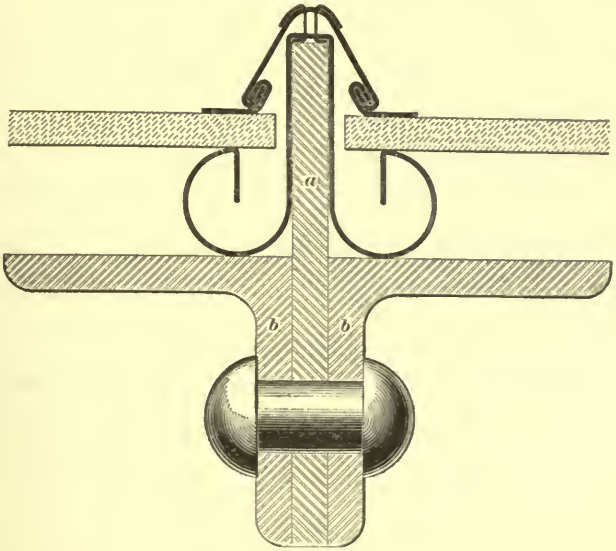


FIG. 117.

of the angles and a gutter is formed over it with caps, etc., as in the previous example.

The tubular construction imparts strength and rigidity and provides for the expansion of the metal and glass. Provision is also made for condensation, as all the bars, vertical and horizontal, act as branch gutters, which are connected to a main gutter.

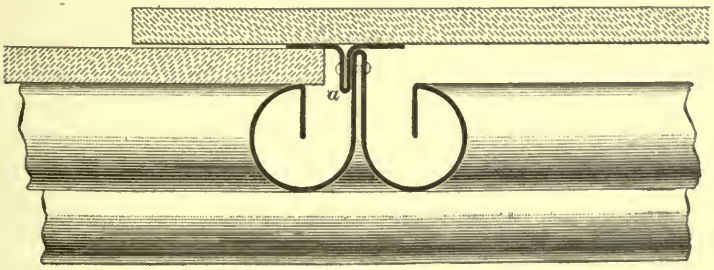


FIG. 118.

138. The glass may be made $\frac{3}{16}$ to $\frac{3}{8}$ inch thick and of any pattern. For plain work, ribbed or hammered glass may be used, the rough surface being placed on the outside. The use of a minimum thickness of glass should, for two reasons, receive consideration: first, the cost of repairs, and, second, the dead load to be supported. The size and strength of the rafters and purlins supporting the ribs must be regulated by the weight of the glass, wind pressure, and snow load.

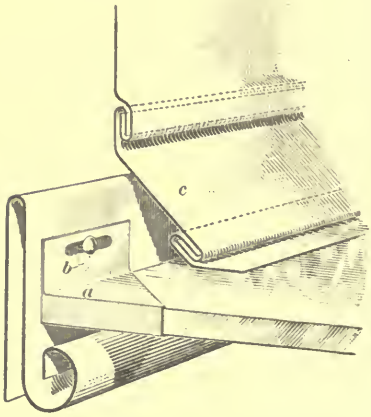


FIG. 119.

139. The horizontal lap joint of the glass, as shown in Fig. 118, is of the same

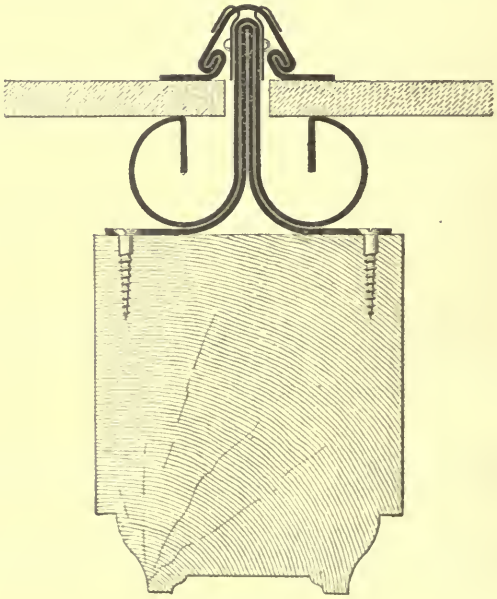


FIG. 120.

construction as the gutter proper, but has a lead fillet *a*, which acts as a cushion and takes up any unevenness of the glass. The lower glass rests on the tube, and the upper on the lead cushion on the top of the rib. The glass should overlap from 1 inch to $2\frac{1}{2}$ inches, according to the pitch. At the end of each light of glass is a stop, or holdfast, made and placed as shown at *a*, Fig. 119. These stops are placed on each side of the vertical ribs, and are secured to the flanges by small screw bolts about $\frac{1}{8}$ or $\frac{3}{32}$ inch diameter. The slot *b* in the flange is cut vertically and is about three times as long as the diameter of the bolt. The slot in the stop or holdfast is cut horizontally and is a trifle longer than the other. These slots provide for adjustment and for any movement that may take place by settlement, and expansion and contraction.

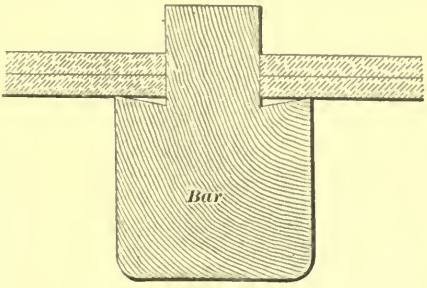


FIG. 121.

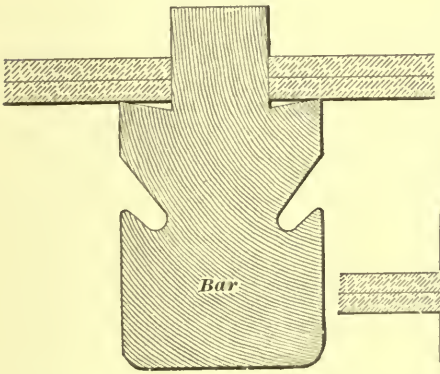


FIG. 122.

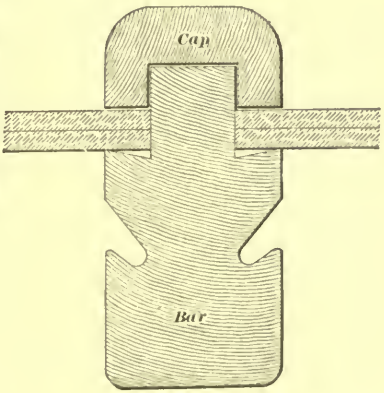


FIG. 123.

The ribs that come against parapet, fire, or other walls are similar to those shown in Fig. 119. The

cap piece *c* is extended and formed into a flashing; it is let into a raglet, and may be covered with a counterflashing.

When the construction to which the glass is applied is of wood, the flange piece is omitted, and the gutter piece rests in and is secured to the woodwork, as shown in Fig. 120.

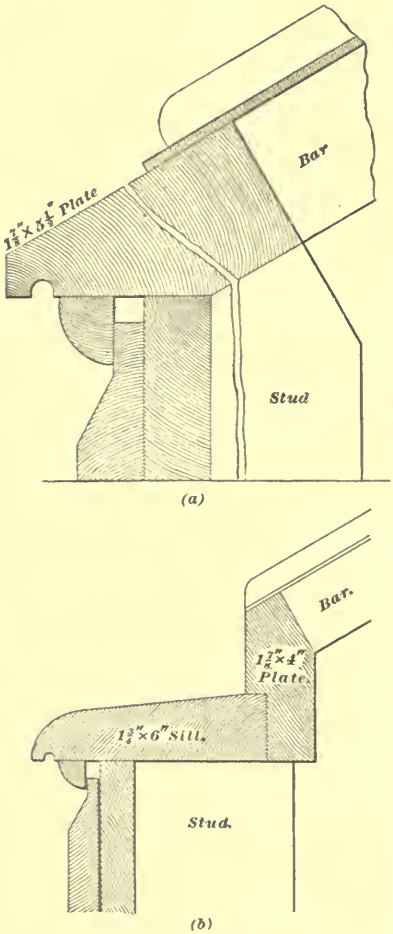


FIG. 124.

140. There are other methods of construction, based upon the same principles, but varying in detail to meet different conditions. For the roofs of greenhouses, etc., where wood construction is used, the durability of the wood should be considered. It has been found that cypress has given better results than any other material. The sash bars may be made, as shown in Fig. 121. The rabbets are $\frac{5}{8}$ inch deep, allowing for the two thicknesses of double-thick glass at the lap, and also for the nailing. The rabbet is formed with a slight bevel, thus forming a channel which carries away any moisture that may enter. The end or gable bars must also be rabbeted, for the roof glass; and where there is a glass gable, these bars must also be rabbeted, to receive the vertical glass.

In Fig. 122 is shown a rafter bar with grooves run in the

sides, to take off condensation; and in Fig. 123 a similar bar fitted with a cap.

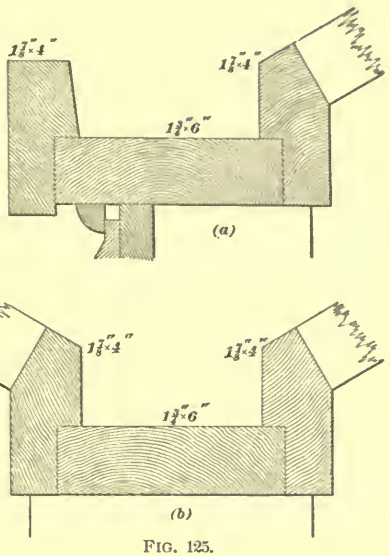


FIG. 125.

141. There are several methods of constructing the plates into which the bars are framed. At (*a*), Fig. 124, is shown a plate made of $1\frac{7}{8}'' \times 5\frac{1}{2}''$ material, beveled and throated to form a drip. At (*b*), Fig. 124, is shown a different construction, in which the plate piece is $1\frac{7}{8}$ in. $\times 4$ in., and the sill $1\frac{3}{4}$ in. $\times 6$ in. The plate is beveled on the top to receive the bar, and rabbeted on the outside to receive the sill. The sill is beveled to allow the water to flow off, and throated to form a drip. At (*a*), Fig. 125, is shown a plate and gutter, the inside or plate having the same construction as (*b*), Fig. 124. If there are two pitches coming together between two ranges of roof, the construction may be as at (*b*), Fig. 125. Gutters, however, should be avoided as much as possible.

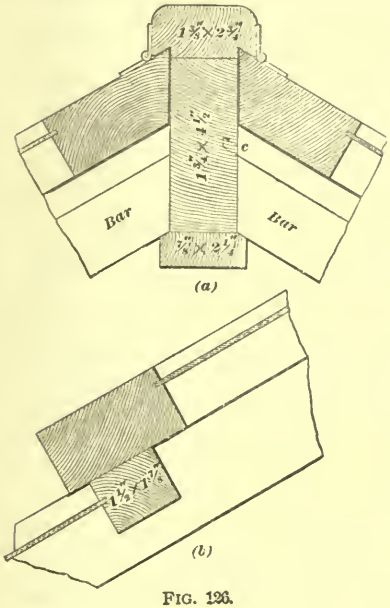


FIG. 126.

142. At the ridge there may be either a single or

double row of ventilators. At (*a*), Fig. 126, is shown a 3-piece ridge, made up of a ridge piece, a shoulder cleat, and a cap. The ridge piece is $1\frac{3}{4}$ in. $\times 4\frac{1}{2}$ in.; the shoulder cleat, $\frac{7}{8}$ in. $\times 2\frac{1}{4}$ in., and the cap, $1\frac{3}{8}$ in. $\times 2\frac{3}{4}$ in., rabbeted to receive the ventilator sash. This ridge is made for a double row of ventilators; if used for a single row, it would be rabbeted on one side for the glass, as indicated by the dotted lines at *c*.

The ventilators should be hinged to the ridge, close against the bars, and a header should be inserted as shown at (*b*), Fig. 126. The header may be rabbeted or grooved to receive the glass. Where the bars are more than 8 feet in length, they should be supported by purlins.

In glazing the sash, the glass is laid from the bottom up, the sheets lapping each other from $\frac{3}{4}$ inch to $1\frac{1}{2}$ inches. The lap is regulated by the pitch, which, in any case, should not be less than 20°.

STONE ROOFS.

143. Stone roofs are not much used at the present time, except for covering small vestibules, porches, turrets, towers,

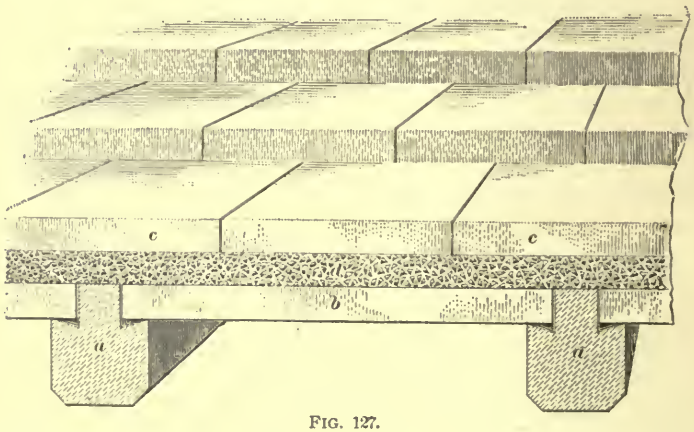


FIG. 127.

and monumental buildings. They may be flat or pitched. Large slabs are used for flat roofs, and small ones for pitched

roofs. They may be laid either with lap or butt joints on a filling resting on the vaulting beneath. For towers and spires, the stone is laid in tiers, either with or without a lap joint.

144. In Fig. 127 is shown the construction of a flat roof, which may be applied either to vaulting or stone purlins, the latter being shown. The purlins *a* are rabbeted to receive the ceiling slabs *b*, and the roof slabs *c* are laid and bedded in cement concrete *d*.

The Greeks, and the Romans after them, used the same method of supporting and laying the roof slab, with this difference, that they cut the slabs, as shown at *a*, Fig. 128, so

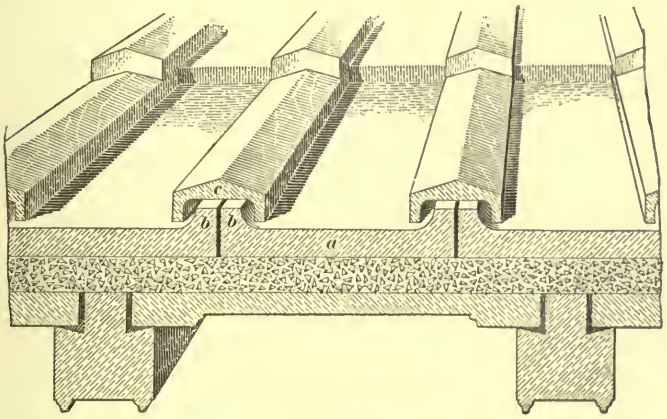


FIG. 128.

that they formed a channel with fillets *b* on each side, and covered the joint with a cap *c*.

For pitched roofs, ashlar slabs are used, laid as shown at (*a*), Fig. 129, in the same manner as shingles with broken joints; the slabs are bedded or laid in cement on the filling over the vault.

At (*b*), Fig. 129, is shown a much better slab roof; the slabs are cut with a rabbet and a lap joint *a*. The cap or ridge stone is made with a rabbet and a lap joint *b* on each side at the edge of the wing, the same as the lower edge of

the slabs. The advantages of the rabbet and lap joint are, that the stones cannot leave the roof if they should work loose, as they would if laid with a simple lap, and there is no open vertical joint for the passage of water.

The plain butt-joint roof is shown at (*c*), Fig. 129.

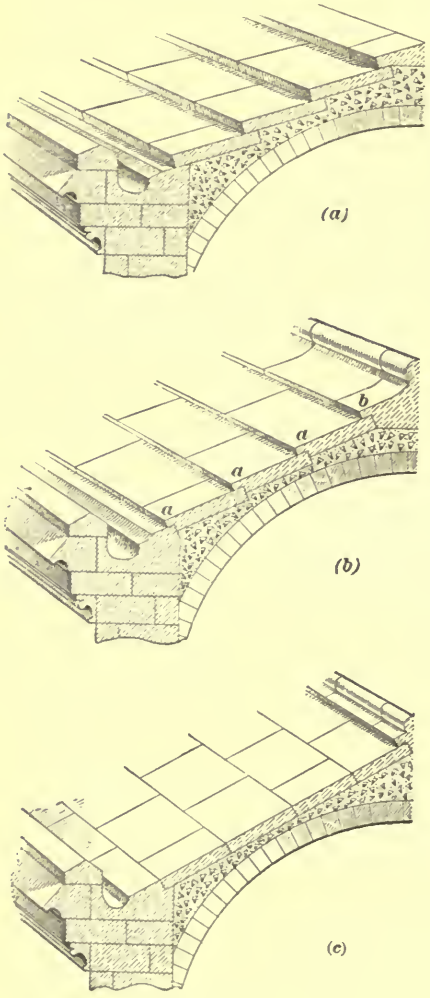


FIG. 129.

The gutters are cut out of a single stone, as at *a*, Fig. 130, the roof slab overlapping it. The water is carried from the gutter through a channel cut in a stone extending the full width of the wall. This channel *b* meets the outlet of the gutter, and extends through the stone to a point outside the wall and discharges into the leader head *c*.

145. For turrets, towers, and spires, the roof, when built of stone, is complete without the

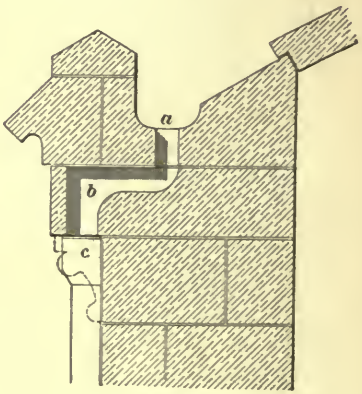


FIG. 130.

interposition of framing. At (*a*), Fig. 131, are shown a one-half elevation and a one-half section of a smooth, flush-faced, conical roof; the beds of the stone are kept level as in regular walling, while the vertical joints radiate from the center of the plan, as shown at (*b*), and bonding as indicated by the dotted lines. The outer surface of the stones used for such roofs may advance, giving the suggestion of a lap only, as at (*c*); or they may be rabbeted and lapped, as at (*d*). The terminal, cap, or finial should commence at a point where the roof stones become too small to look well, as at *e*, and should be, preferably, of one piece of stone.

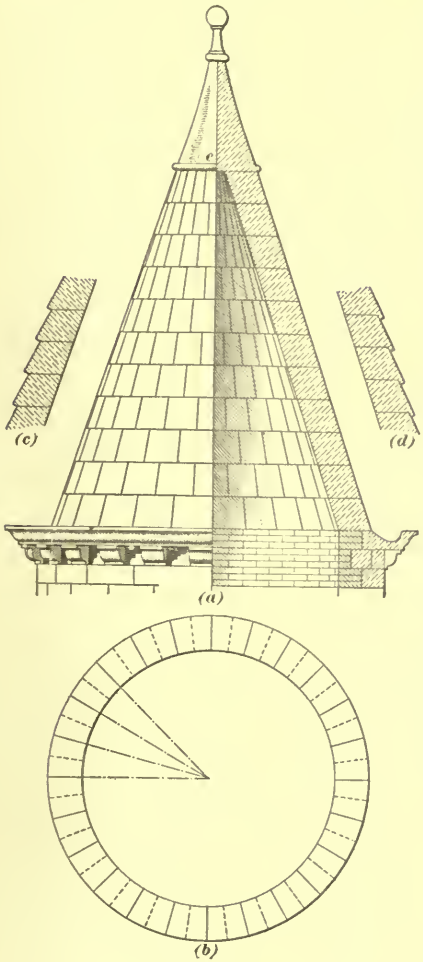


FIG. 131.

FLAGPOLES.

146. The curve, taper, or entasis of a flagpole may be developed by the following method: the diameter at the base where it emerges from the roof should be about $\frac{1}{50}$ of the height, and the diameter at the top or head should equal $\frac{1}{2}$ the lower diameter. Assume a flagstaff 50 feet, or 600 inches, long; its diameter would be $\frac{1}{50}$ of this height,

or 12 inches, while the diameter at the head would be 6 inches.

To obtain the entasis, draw a center line $a\,d$ through the pole. See Fig. 132. Divide $c\,d$ the lower half diameter as follows: from d mark a point equal to one-fourth of the lower diameter, as $d\,e$; divide the remaining distance $e\,c$ into two equal parts as at f, and divide the distance $c\,f$ into two equal parts as at g, and again, divide $c\,g$ into two equal parts as at h. Divide the vertical height of the shaft into four equal parts by horizontal lines; transfer the distance $d\,e$ to $d'\,e'$; $d\,f$ to $d^2\,f'$; $d\,g$ to $d^3\,g'$; and $d\,h$ to $d^4\,h'$; then through the points marked, draw the curved outline.

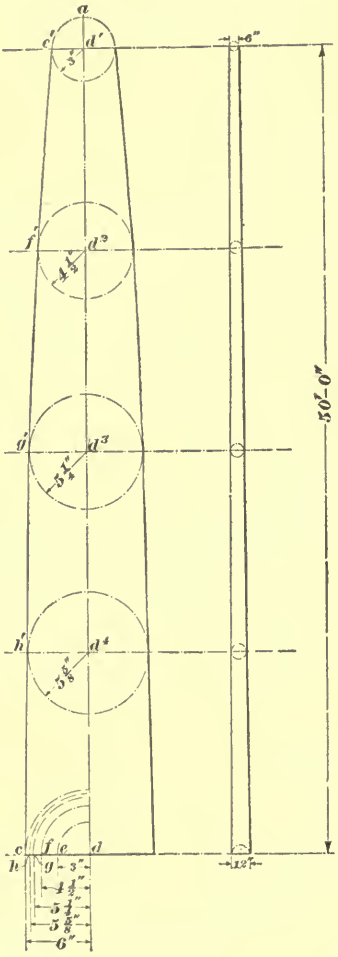


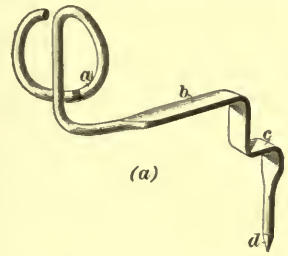
FIG. 132.

SNOW GUARDS.

147. Snow guards made in various forms are used on all kinds of roofs to prevent the snow from sliding down into the gutters, thus clogging them, and causing the water to overflow outside of the building. Where snow accumulates and freezes in a gutter, it is likely to form a dam and back the water up under the slate, tile, or shingles, as the case may be, and eventually finds its way into the interior of the house. Snow guards also prevent the dislodgment of large quantities of snow, which

might cause injury to persons in the vicinity, as well as to ornamental shrubbery. For these reasons they should be applied to roofs having a steep pitch towards the street.

148. The guard generally used is made in four different styles, and is constructed with galvanized-iron or copper wire. At (*a*), Fig. 133, is shown a



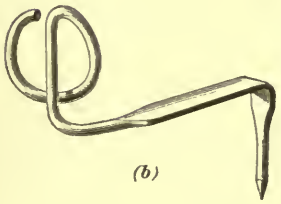
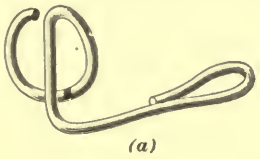


FIG. 133.



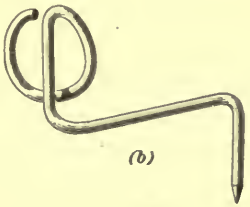


FIG. 134.

guard used with convex tiles; the loop *a* acts as the snow stop and stands above the tile about 2 inches; the shank *b* is of sufficient length to extend well back on the tile, and is made flat so that it presents the least thickness at the tile lap; the end is turned down and out and is kept flat at *c*, to give a driving surface over the nail point *d*, and to raise the guard to the height of the tile.

At (*b*), Fig. 133, is shown a guard made for flat or concave tiles; the loop and shank are the same as at (*a*). The nail point is turned down without forming a knee, because the tiles do not stand more than $\frac{3}{8}$ inch above the roof.

At (*a*), Fig. 134, is shown a guard used for metal roofs, with lock seams. It is secured to the roof under the lock by a galvanized-iron nail driven through the loop at the back.

At (*b*) is shown a guard used for slate or shingle roofs. This guard is set between the edge joints of the slates or

shingles, and the nail point is driven into the roof boards. Should this form of guard be bent down by the weight of snow and ice, it may be readily pressed back, without breaking, into its proper position. Guards are also manufactured of cast iron, but, being clumsy, they are not to be recommended.

Guard rails are also clumsy and unsightly; they gather the snow in a drift, which dams up the water, with the result before mentioned; on the other hand, the wire snow guards placed all over the roof are almost invisible, and hold the snow until it melts and disappears.

SHEET-METAL WORK.

USES OF SHEET METAL.

1. The greater part of sheet-metal work used in building construction is employed for the following purposes:

1. For covering and flashing roofs and their intersections, so that the roofs may conveniently be made watertight.

2. For wall covering and the formation of columns, cornices, balustrades, and string and molded courses. In some cases the entire outer surface of the walls of a building is covered with sheet metal, the material being made to resemble masonry or brickwork, an effect produced at low cost. Frame buildings may also be covered with sheet metal in order to render them less liable to fire from adjacent structures.

3. In forming gutters, valleys, or other water channels that are graded down to certain points of outlet, so that the rain which falls upon the roof may be conveniently drained away, thus preventing the roof water from being shed upon the ground around the building.

4. For conductor pipes, sometimes called leader pipes, which are commonly secured against the outside walls of a building to connect the lowest points of the roof gutters with an underground drainage system, or simply to a drainage

above the surface of the ground, so that the roof water may flow freely away from the gutter.

5. For covering domes and lanterns, and in forming crestings and finials.

6. For interior decorations, such as the covering of walls and ceilings where first cost is an important factor; or, for the covering or formation of the inside trim, doors, windows, casings, etc.

7. For flues and other conduits commonly employed for purposes of ventilation.

While there are other positions and features where sheet metal may be employed, a thorough knowledge of the foregoing examples should enable the student to reason out, and solve, any special problem that may present itself.

EXTERIOR SHEET-METAL WORK.

INTRODUCTION.

2. The general subject of sheet-metal work for roof coverings, flashings, etc., has been treated in the section on *Roofing*, and the application of sheet-metal work for ventilating purposes is dealt with in the section on *Heating and Ventilation;* consequently this portion of the subject will not be considered in this section.

3. The kind and class of exterior sheet-metal work required, will of course depend upon the character and purpose of the building. Mills, factories, workshops, warehouses, etc. are often covered with galvanized sheet iron in the plainest possible manner, with no pretensions to artistic treatment, while store and office fronts are often covered with sheet metal bent and formed into elaborate moldings, or pressed and stamped into ornamental details, which are grouped so as to form decorative features. Generally speaking, sheet-metal coverings for buildings are imitations

of brickwork or masonry, and when properly arranged and attached to a good solid backing and carefully painted, they make, for some time, successful deceptions.

Sheet-metal fronts and other wall coverings are employed only when the desire for ornamentation exceeds the owner's willingness or capability to pay for the genuine article. From a speculative point of view they may be paying investments, providing the metal is protected against corrosion; but from an architectural or engineering standpoint, they are utter failures.

WALL COVERINGS.

4. Wall coverings may be classed as plain and ornamental. Plain wall coverings are used chiefly on buildings intended for manufacturing purposes and for such structures as are erected for temporary use; while ornamental coverings are generally used on the fronts of cheap city buildings, such as warehouses, stores, theater fronts, etc.

5. The sheet metal employed for this purpose is usually galvanized sheet iron or steel, the sheets being either **plain, crimped,** or **corrugated.**

Plain sheet iron is seldom used except for the most ordinary work, where appearance is not at all considered. The sheets are simply nailed to a backing of matched lining or ordinary sheathing, the object usually being to prevent the building from readily becoming ignited, should an adjacent building be on fire.

The chief objection to plain sheet siding, is the fact that the metal will bulge and become distorted in many different ways, until the whole side of the building will actually appear to be covered with large blisters.

6. *Crimped* sheet iron is superior to plain sheet iron for covering large flat surfaces, because the crimping helps to prevent the sheets from bulging, and thus, to

a certain extent, avoids the blistered appearance so pronounced on plain sheet-iron siding. A clipping of crimped sheet metal is shown in Fig. 1. The sheet is crimped by passing it through ribbed or roughened rollers, which give it the appearance of being slightly corrugated. Crimped metal, however, differs from corrugated metal in that sheets of the former, after treatment, are practically as long as they were before the process, while in corrugating the sheet is shortened. The crimps are usually made across the sheet, while corrugations are run lengthwise.

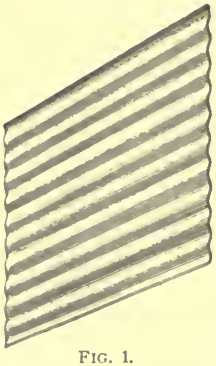


FIG. 1.

Crimped sheets may be nailed to furring strips, or to studs or posts set at from 12 to 16 inch centers, providing the grooves run at right angles to the strips or studs. Thus, if furring strips are nailed on the studding, the grooves would be vertical, but if the sheets are nailed directly on the studding, the grooves would be horizontal. It is best, however, in every case to provide a solid flat backing for crimped sheet-metal work.

7. Corrugated sheet iron is preferable for siding where there is an extensive, unbroken surface. The corrugations not only strengthen the sheets, and thus enable them to be attached to furring strips as far apart as 4 feet, but they also relieve, by the play of light and shade, the monotony incident to a flat surface.

Corrugated sheet iron should always be fastened with the corrugations vertical, not so much for appearance as to

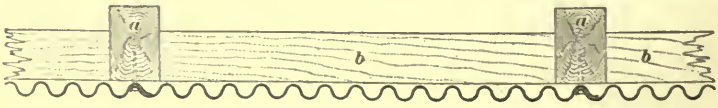


FIG. 2.

obtain a perfectly water-tight siding with ordinary lap joints. Fig. 2 shows the method of forming vertical joints. The corrugations are simply lapped and the two sheets are nailed

to the posts or studs a, a with flat-head galvanized-iron nails. The top edge of each sheet is nailed to cross-pieces b, b which are spiked or framed in between the posts. The horizontal joints of the sheets are lapped as shown in Fig. 3; cleats are riveted on as shown at a to bind the lower end of the sheet so as to make a close joint and also allow for expansion and contraction of the sheets. The top sheet should lap at least 2 inches over the nails.

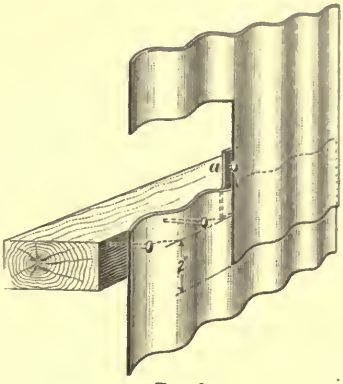


FIG. 3.

Corrugated-iron sheets are often secured against sheathed walls, and the common practice is to nail them all around the edges, but, in this case, expansion and contraction soon loosen the sheets either by drawing the nails or by tearing the nail holes. The plan of attachment described above and illustrated in Fig. 3 is to be recommended even when the sheets are secured against a flat surface.

8. Fig. 4 shows how the corrugated sheets may be put on at the base of the framework. A **base strip** a, made in the form of an offset, is securely nailed to the wooden sill b, the strip being flanged so that it may cover the exposed portion of the wall. The sheets are clamped to the top edge of this strip with cleats 1 inch wide by $\frac{1}{8}$ inch thick, similar to that shown in Fig. 3.

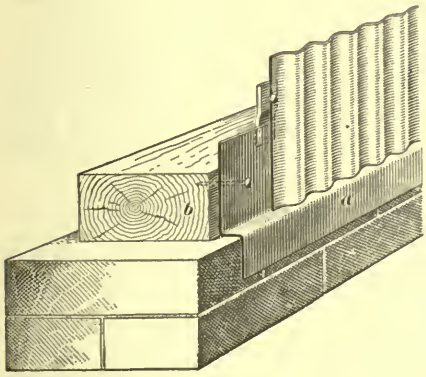


FIG. 4.

9. Fig. 5 shows the finish of the sheets at the eaves. The top edges are nailed to the plate *a*. A strip of wood *b* about

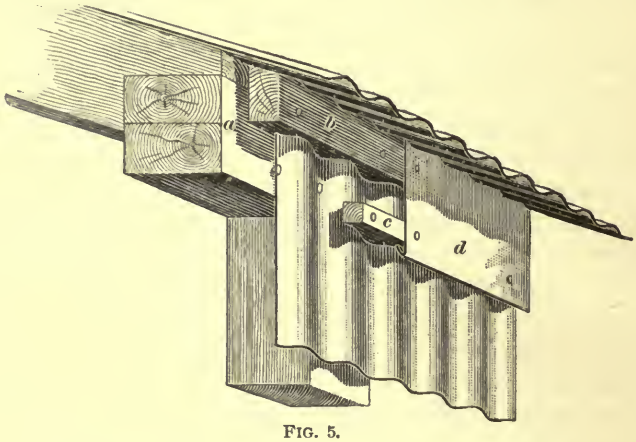


FIG. 5.

$1\frac{1}{4}$ inches thick, cut on one edge to fit the profile of the corrugations of the roof, should be nailed to the upper edge of the plate. Another strip *c* of the same material is nailed to the lower edge of the plate. A facia of crimped sheet iron *d* covers both strips and forms a drip at its lower edge, as shown. This arrangement makes a neat, water-tight, and wind-proof connection between the siding and the roof.

10. Fig. 6 shows the finish at the corners of the building; this makes a water-tight junction and presents a neat appearance. Since the corrugated iron is laid against the framework, it is necessary to nail $\frac{7}{8}$-inch wooden strips on the outer faces of the corner post *a*. The corrugated iron butts against the edges of these strips, and a crimped sheet-iron corner piece, is sprung over and locked into the corrugated wall sheet, as shown.

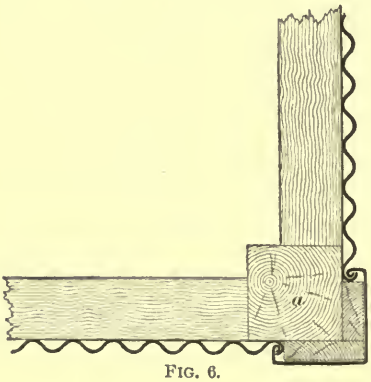


FIG. 6.

This arrangement can also be used around any window or door opening. The arrangement shown in Fig. 4 may also be used over the lintels of any door or window opening.

11. Corrugations in common use measure about $2\frac{1}{2}$ inches, from center to center, and are about $\frac{3}{4}$ inch deep.

Black corrugated iron should always be painted with metallic paint of the best quality before it is secured in place.

12. **Stamped siding** is most commonly employed for covering large flat surfaces of outer walls, the sheets being pressed to such a shape that they resemble **rock-faced,** or **tooled,** stonework or brickwork. This siding is stamped in plates 10 feet long by 2 feet wide, and the plates are sold by the lineal foot. Like crimped sheet metal, it is nailed to furring strips, to ordinary sheathing, or to brick walls, the vertical joints being lapped and closely nailed.

Particular care should be taken to lap all the vertical joints in sheet-metal work so that the heaviest rain storms will blow with the laps and not against them. It is noticeable in nearly every district that the strongest winds and greatest rain storms nearly always blow from certain directions; these directions should be determined, and the sheet-metal work should be arranged to prevent the rain from blowing into the seams.

Brick walls should always be thoroughly furred to receive the sheet-metal work. It is a mistake to suppose that sheet-metal work can be securely nailed into the joints, because expansion and contraction will very soon loosen the fastenings.

CORNICES.

13. Sheet-metal cornices are made in such a variety of patterns, in such a wide range of sizes, and are required to be placed in such a diversity of situations, that there must be a great variation in the methods of construction. Very many designs, however, correspond as far as having moldings continuous throughout their lengths. All are supported

by projecting brackets or lookouts. The joints, shape, and material of the cornice proper, and the construction of lookouts, are the features in cornice work which we will consider in particular.

Cornices are made at the cornice factory according to drawings and specifications, and are shipped in parts to the building.

Brackets, modillions, dentils, etc. are usually secured to the cornice at the factory. Trusses and check or stop blocks are shipped in separate packages. Thus it will be seen that the cornice setter or tinsmith is only required to assemble the several parts and erect them in place on proper supports. The supports in general use are wood or iron, the latter being employed in the better class of buildings.

14. Cornice Erection on Wood Supports.—Fig. 7 shows the parts and joints in a sheet-metal cornice as ordi-

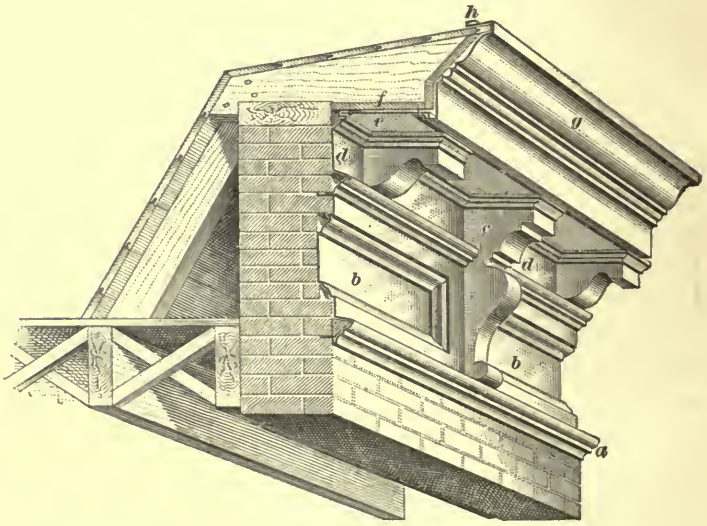


FIG. 7.

narily constructed in small sections on a brick wall. The foot molding *a* is fastened to and supported by a board and wooden lookouts, the lower member being allowed to hang down below the raglet or groove which runs along the joint

of the brickwork at the underside of the lookouts. The top of the foot molding enters the raglet in the next joint above. The paneled frieze *b* is made up in one piece between the trusses or brackets *c*, the edges being doubled over and secured into raglets as shown. The modillion course, which generally includes the small moldings above and below the plain surface from which the modillions project, is attached to the brickwork in a similar manner and is secured in place with a long, narrow, metallic wedge. If the cornice is erected while the walls are being built, the upper flange of each piece is usually bent over far enough to be safely bedded in; the lower edge of the sheet above being bent over and pushed into the same joint as the work progresses. The soffit *e* may be bent up out of the same piece with the bracket molding. The drawing, however, shows it separate, and secured to the board lining *f*.

The **crown molding** *g* is bent over the top of the roof boards, leaving an edge turned up as at *h* for easy connection to the sheet metal of the roof. The lower edge of the crown molding should be made to form a drip, as shown, and should be securely nailed to *f*.

The brackets and trusses which are hollow and built up from stamped sheet metal are riveted and soldered in position. It is difficult, however, to properly attach them when the cornice is put up in sections, as shown, so it is advisable to have these projections riveted and soldered on before the cornice is put up. In the construction of cornices, particular care must be taken to avoid pockets in which water may accumulate. If there is any suspicion of a water-tight pocket, a small hole should be punched at the lowest point to allow any water to drain out. If this is not attended to, these pockets may fill up with water, freeze, and burst.

15. Another plan for securing cornices against brick walls is to spike boards against the face of the walls, plant the cornice on top of the boards, and nail it in place. The former method, however, is preferable, not only because the nails must show by the latter method, but chiefly because

the boards will warp and the cornice will consequently become distorted and loosened.

The cornice work shown in Fig. 7 is attached to a brick building with a flat roof. The roof pitches down to the back of the building and the conductor pipes, of course, are in the rear. When the roof pitches in the direction of the cornice, a gutter is usually formed at the back of the crown molding.

16. Iron Supports.—It is comparatively easy to secure a sheet-metal cornice to a wooden building, or even to woodwork which is spiked to brick buildings; but it is considerably more difficult to properly secure a cornice to brick, stone, terra cotta, or to the structural ironwork of the modern fireproof building.

Fig. 8 shows a system of bracing well adapted for a cornice at the top of a brick wall. The framework or bracing shown, which is mostly composed of angle irons, should be built into the wall. These frames should be placed from 2 to 4 feet apart, according to the projection. The cornice is sometimes bolted to the framework after the wall is finished.

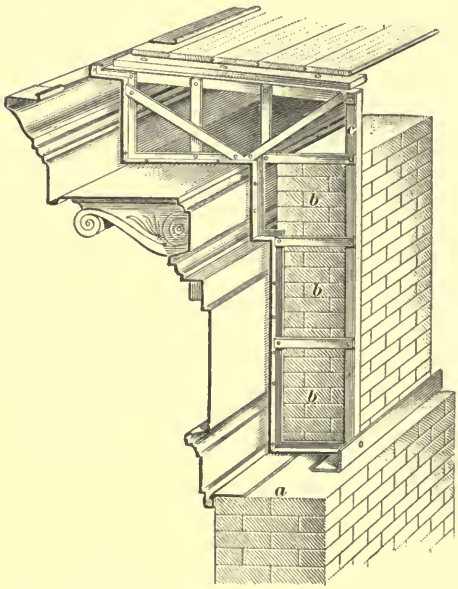


FIG. 8.

The strongest and best plan, however, is to attach the iron frames to sections of the cornice about 14 feet long and hoist the sections up, and set them on the wall when it has been leveled at the required height as at *a*. When lined up and in proper position, the frames are tied

temporarily in place to keep the cornice from toppling over until the brickwork *b*, *b* is all filled in and has set. This mass of brickwork must be sufficient to more than counterbalance the weight of the cornice. If there is any danger of the cornice being too heavy for the counterweight, the legs *c* must each be tied separately to some beam or other rigid part of the building.

There are, of course, many kinds of iron supports for cornices other than that shown in Fig. 8, but with a little judgment the student should be able to design a lookout for any position. The principal points to be considered in such a design are: (1) to obtain a band of iron which will follow, in a general way, the contour of the cornice; (2) a means to brace this iron band and prevent it from changing its shape; (3) a means of rigidly securing the iron band to the building; iron beams, or columns, being preferable for anchoring points.

17. Joints in Cornices. — Different mechanics have different methods of making vertical joints in cornices; some of these are very neat, strong, and durable, while others should not be tolerated. The only two joints worthy of mention here are the *butt joint* and the *lap joint*.

18. A **butt joint** is shown in Fig. 9. The edges of the sheets *a*, *a* which form the cornice are trimmed perfectly square and straight, so that when brought together they will fit closely. A strap *b*, which is made from the same metal as the cornice, is then riveted the entire length of the vertical seam, and its edges are soldered to the back of the cornice, as shown. The rivet heads are all on the outside, and the process of riveting draws in the heads and makes them scarcely visible. The rivets should be as close together as possible.

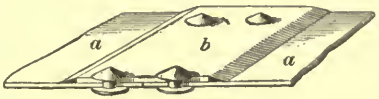


FIG. 9.

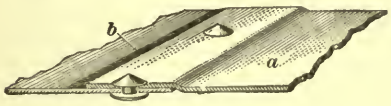


FIG. 10.

Fig. 10 shows a **lap joint**. The sheets are lapped over one another for a distance of

$1\frac{1}{4}$ inches and then riveted closely. The back sheet is dressed forwards to be flush with the other, as shown, and the back edge is then soldered, as at *b*.

19. Both of these joints are strong and durable. The butt joint, however, is neater than the lap joint. A first-class mechanic can make one of these joints so that a perfectly smooth surface will be obtained.

The *rivets* for galvanized-iron cornices should weigh $1\frac{1}{2}$ pounds per thousand, for Nos. 24, 26, 28, and 30 sheet iron. The rivets for copper cornice work should weigh 1 pound per thousand.

20. **Cornice seams,** or horizontal joints, are also made in a variety of ways, but the following methods illustrate good practice when the joints must be made on the job.

Cup joints are shown at *a* and *b*, Fig. 11. The position of the copper in these joints shows how they appear when the cornice is being fitted up. After the cornice is lined up in place and the vertical joints are all made, the edges are bent over twice, thereby locking the seams. These joints are necessary only in large cornices.

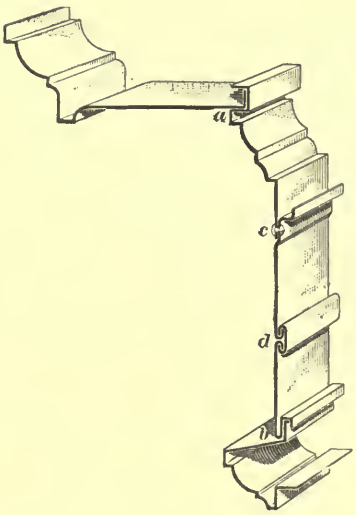


FIG. 11.

When a seam must be made on a flat surface, such as on a wide frieze, either of the methods shown at *c* or *d* may be employed. The seam at *c* is lapped and riveted like that shown in Fig. 10; a stiffener, however, is bent at the back to keep the seam straight. This is the stronger seam of the two. It is preferable to that shown at *d* in places where rain will wash over it. When it is desired to form a very close horizontal joint, the **clinch seam** at *d* may be used. The edges of the sheets

are bent over and butted together in position. The cap is then slipped over the seam as shown. When the work is all lined up, the seam is closed by flattening down the cap. This process draws the sheets together and makes a very close seam.

21. Miters.—All miters in cornice work, pediments, and elsewhere may be classed as *lap* miters or *butt* miters.

Outside miters are made in different ways, but there are only two reliable methods. The first, or lap miter, is made by returning a $\frac{1}{2}$-inch flange on the inside of the miter, as shown in Fig. 12. This flange must be riveted closely and soldered on the inside. The chief objection to this miter is that the edge of the sheet is visible.

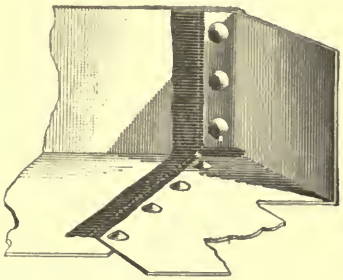


FIG. 12.

To make a close miter it is necessary to bevel and butt the edges as shown in the butt miter, Fig. 13. In this figure the edges of the copper are fitted closely together.

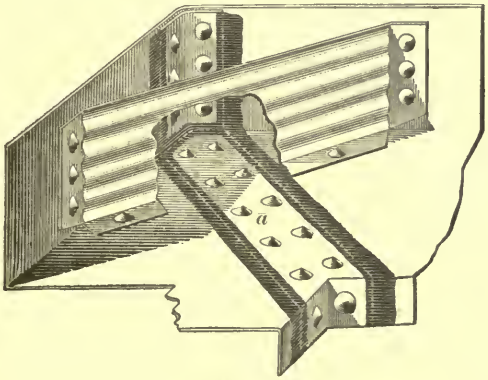


FIG. 13.

A copper angle strap *a* is then riveted and soldered securely in the inside angle the full depth of the cornice. A few gussets are then riveted and soldered across the inner

corners as shown. They help to keep the cornice square during shipment and prevent the edges from being pulled apart by expansion and contraction. The method shown in Fig. 13 should be used on all first-class work.

Inside miters are made and reinforced in a similar manner, but owing to the fact that gussets cannot be used, it is advisable to rivet a reinforcing angle strap over the half-inch flange.

22. Iron-Beam Cornices.—In some buildings the iron-work of the first story or "store front" does not project beyond the wall; and the iron beams, such as those over store windows, often require to be covered with a metal panel or cornice, or both combined.

Fig. 14 shows a **panel course** attached to an iron **I** beam. A series of bar-iron braces *a* are fastened to the web of the **I** beam and the panels are secured to them with countersunk screws, so that the heads will finish flush with the face of the panel. A rebate is formed at *b* to cover the joint between the top of the window frame and the iron beam. When the beams are in place, and before the brickwork *c* is built thereon, the sheet-metal panel course is pushed over the face of the beam and doubled over at the back edge of the upper and lower flanges, as shown at *d*. The braces *a* thus merely support the frieze and prevent it from sagging. If desired, a plank instead of iron straps may be bolted to the web of the beam to support the panels.

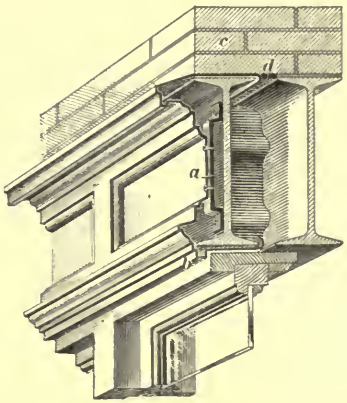


FIG. 14.

23. String-Course Cornice.—A string-course cornice, or store cornice as it is often called because it is so commonly used over store fronts, is shown in Fig. 15. The lookouts are

made of band iron $\frac{1}{4}$ in. $\times$ $1\frac{1}{2}$ in. and are tied into the brickwork at *a* and *b*, these ends being built into the wall. The lower ends of the lookout frames are continued down over the face of the beams and along under their lower flanges, and are then bent up at the back, as shown at *c*. An angle iron at *d* running the whole length of the cornice is bolted to the ends as shown at *c* and keeps them in place. A sloping platform of matched boards is screwed on the top of the

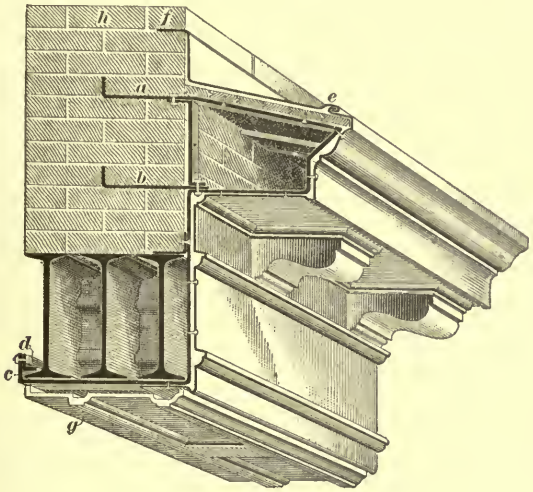


FIG. 15.

lookouts. The sheet-metal work is bolted to the band iron in the usual manner, a soldered double seam with cleats is made at *e*, and the top covering enters the wall at *f*. An iron plate, either plain or ornamental, is usually secured at *g* to form the soffit of the beams over the opening.

After the beams are set on their columns, and before the mason begins to build on them, the cornice must be set in position. The cornice being set true and level, the mason finishes the wall up to the course *h*; then the flashing is put on, the top edge *f* being bent over about 3 or 4 inches, as shown. When this is finished the mason proceeds to build the superstructure. If the wall is built before the cornice lookouts are ready, the anchors *a* and *b* must pass through

the wall and be bent over at the back, and the flashing *f* must be let into the raglet and be batted with lead, the raglet being filled with mastic or other cement in the usual manner.

24. In many cases it is advisable to make the lookouts of cast iron instead of wrought iron, as, for example, when a very large number of small lookouts having the same shape are required. If the molding is small and extends as a belt, or string, course around the building, it is certainly advisable to use cast-iron lookouts. The chief advantages of cast-iron lookouts are accuracy in the lines of the cornice, economy in construction, and durability.

Accuracy is insured when the lookouts are properly lined up, because each lookout is a duplicate of the others, they being all cast from the same pattern. Economy of construction lies in the fact that the labor of making the lookouts and of fitting the sheet metal to them is reduced to a minimum. And the durability lies in the fact that cast iron is less corrosive than wrought iron. Iron lookouts should always be coated with asphalt or other protective covering in order to prevent rapid corrosion.

25. Galvanized iron should never be used for cornices except in the very cheapest work, and even then it should be thoroughly painted on both sides. Sheet copper (cold rolled) is preferable, however, in every case. The metal itself costs considerably more than iron, but the labor and other expenses, relative to its construction and installation, are about the same.

26. Copper cornice work does not require to be painted for protection. It is, in fact, better practice to leave the metal thoroughly scoured, clean, and uncovered, and allow the weather to slowly change its color. Copper sheet-metal work has naturally a dark-green tint, but it often takes a very long time to get that color. The time required will depend considerably upon the climate, the weather, and the composition of the atmosphere. Where the rain becomes acidified, by falling through air charged with sulphurous

gases, the color changes rapidly, but where it falls pure and clear, the copper changes color very slowly.

When it is desired to hasten the color it is customary to produce an *artificial* color by washing the copper with acids. One method is to thoroughly scour all the copper work to remove any grease or acid spots, then wash the entire surface with a solution composed of 1 pound of sal ammoniac to 5 gallons of water. This solution should stand about 24 hours before it is applied. After the copper has been uniformly covered with the solution, it should be allowed to stand for a day or two and should then be lightly sprinkled with clean water. If the water is put on too freely, it will run in streaks. After a few days the copper work should have a beautiful and uniform greenish-brown color which will stand the weather. The same effect may be produced by using vinegar and salt in the proportion of ½ pound of salt to about 2 gallons of vinegar.

27. Soldered Seams.—Although it is advisable in all sheet-copper work to solder the seams on the back where they cannot be seen, it nevertheless often happens that some parts must be soldered on the front. The solder does not change color like the copper, and, consequently, when not properly treated, such seams tend to spoil the appearance of the work.

To give solder a copper color, it is necessary to deposit a copper plating upon it. This is accomplished by first thoroughly scouring the seams, then washing them with a solution of *sulphate of copper* and water. The solution should be strong. When applied with a brush to the solder, a film, or plating, of metallic copper is immediately formed over the solder, and, by repeated applications, a fairly substantial coating of copper is obtained.

WINDOW SILLS, LINTELS, AND CAPS.

28. *Window sills* are made of sheet metal to represent cut-stone sills. They should be filled in behind with timber of the proper size. The metal sills are usually slipped over

the wood backing and secured to the wall by nailing closely through the flange *a*, Fig. 16, which extends along the bottom and up the sides. The top flange *b* is made wider than that at *a*; it is nailed against the window frame and is bedded in white or red lead to make it watertight. A better plan, however, is to bed the window frame over the metal sill with red or white lead, the metal being flanged and passing up into the groove *c*. Metal window sills are generally used on galvanized-iron fronts. Copper is seldom used for this work.

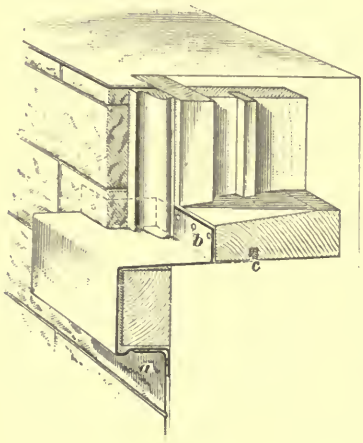


FIG. 16.

29. *Window lintels* are covered in a similar manner, the chief difference being that the top flange of the lintel is overlapped by the metal siding above it. The soffit of the lintel flanges down against the top of the window frame and is nailed to it. Particular care, however, should be taken to have a well inclined wash on the lintel. Horizontal surfaces, particularly pocketed surfaces, are very objectionable and should always be avoided.

30. The covering of bay windows, architraves, pediments, etc. depends altogether upon the design. An important point to be considered in the line of sheet-metal work for bay windows, pediments, etc., is the provision for lookouts and other projections to which the cornice and other moldings must be attached. Small moldings are usually planted on the flat, sheathed surfaces, while lookouts are required for the cornice and other large projections. It is advisable, on all the work, to provide solid backing for the sheet metal. When wooden lookouts are used, they should be so made that the metal work can be nailed across the

grain of the wood, not with it. The expansion and contraction of the metal soon draws out and loosens all nails which are driven in the direction of the grain.

31. *Window caps*, like all other ornamental parts of sheet-metal work, are made up from stock sizes and shapes of bent or stamped sheet metal. Fig. 17 shows a sheet-metal

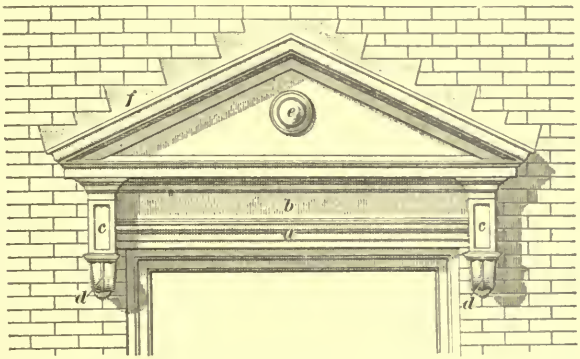


FIG. 17.

window composed of an architrave *a*, a frieze *b*, and two impost blocks *c*, *c* supported by brackets or trusses *d*. The impost blocks support the pediment *e*, and a counter-flashing at *f* makes the top water-tight against the brick wall. If the cap is put on after the walls are up, it is customary to secure it in place against wooden lookouts, as shown at *b*, Fig. 18. Furring strips *a*, *a* are nailed to soft pine plugs, previously driven into the wall, and the lookouts *b*, Fig. 18, are set about 1 foot apart along the line of the furring strips and nailed

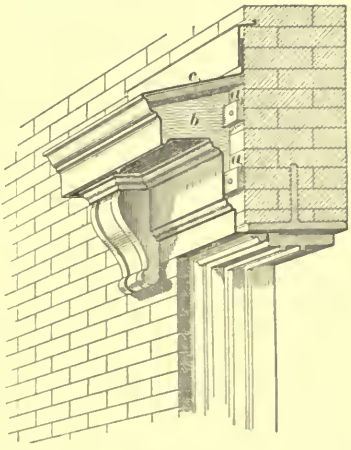


FIG. 18.

to them. Two special lookouts are secured to support the trusses. The sheet-metal cap is then set over the lookouts and is rigidly nailed to them. The metal is extended under the soffit of the lintel and flanged down against the hanging tile of the window frame, and is neatly finished with an angle molding bedded in white lead and well nailed in place. The wash *c* of the cornice is turned up against the wall and is counterflashed in the usual manner.

If the wall has not been built, it is advisable to use iron lookouts and build them in the brickwork when the wall has been brought up to the proper height. The upper surface of all window caps, sills, and cornices should be carefully protected during the erection of the building. Every window cap, and indeed every other projecting molding or cornice, should be closed water-tight on top with a sloping deck or wash, and should be sufficiently strong for a man to walk along the projection.

COLUMNS.

32. There are many different kinds of columns and pilasters, and different methods of constructing them. In a general way, however, Fig. 19 illustrates common practice. This figure shows in elevation at (*a*), and in section at (*b*), a three-quarter column, such as is used on the front of a building. The column is braced by wooden blocking, composed of 1½-inch or 2-inch horizontal blocks *a*, *a* which are spiked to an upright post *d*, and spaced at intervals of not more than 2 feet. Vertical strips *b*, *b* are nailed to the face of the blocks, and are run from the square plinth *c* to the top of the capital. The sheet metal which forms the column is continued down to the plinth, and up to the block or other member over the capital, the seam on *c* being soldered water-tight. The back edges of the sheet are nailed to the face of the wall in the ordinary manner. The base is then put in place and soldered to the column. The capital should then be soldered to the column. This is one of the best methods of bracing sheet-metal columns.

In fireproof construction the same method is employed, except that iron is used instead of wood. Pilasters are formed and covered in the same manner as columns. In all column and pilaster construction, avoid the formation of pockets wherein water may accumulate.

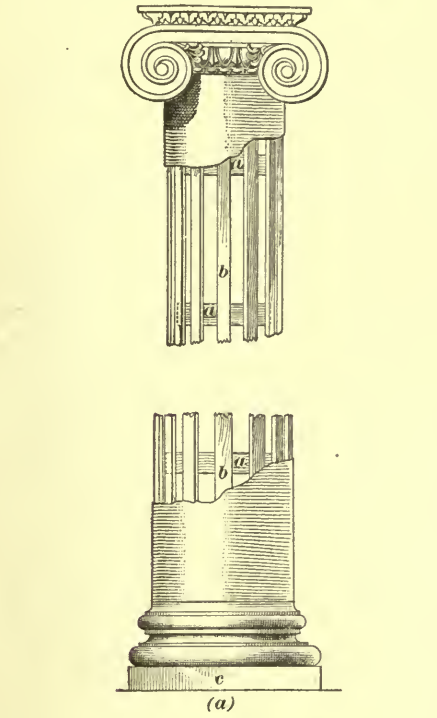


FIG. 19.

FIRE DOORS AND SHUTTERS.

33. Wooden fire doors may be covered with any kind of sheet metal which has a high temperature of fusion. Copper and zinc are not suitable for this work; galvanized iron and tin are therefore used, though tin seems to have the preference. The covering is generally put on as follows: The outer edges of the door are covered first with a strip of tin, which is returned over both faces to a distance of about 6 inches, the edges being nailed to the woodwork and turned over, as shown in Fig. 20. The flat part of the door is then covered with sheets 14 in. × 20 in., in a manner similar to that employed

on flat roofing. This arrangement avoids seams around the edges of the door, and allows it to shut with a close contact.

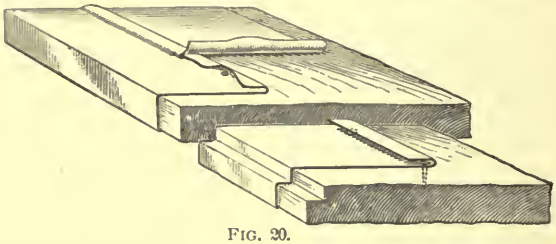


FIG. 20.

A heavy body metal should be employed for this work, because the efficiency of the covering in case of a fire depends upon the thickness of the metal, and not upon the thickness or quality of the protecting coat. The seams should all be closely nailed, and then locked and thoroughly pounded down. A layer of asbestos cloth should be placed between the tin and the wood.

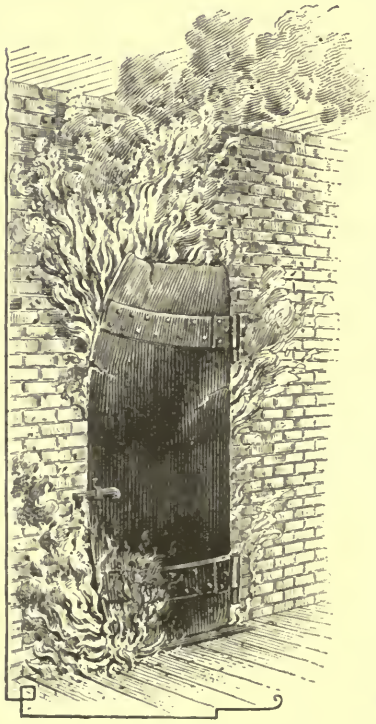


FIG. 21.

Corrugated-iron doors and shutters are also extensively used, but they do not form as efficient fire stops as ordinary wooden doors or shutters which are properly covered with tin and asbestos. The corrugated iron must be thoroughly braced with an angle-iron or **T**-iron frame.

The chief objection to iron fire doors and shutters is that they warp very easily when the flames touch them. Plain iron warps so much that it is practically useless as a fire

stop. Fig. 21 furnishes a good illustration of this. The door shown is composed of one sheet of thick metal, and is provided with iron cross-pieces to which the hinges are riveted. The fire plays against the inside of the door and warps the sheet outwards, thus allowing an opening for the flames, as shown.

COPINGS.

34. Wall Copings.—The tops of all brick walls must be made water-proof, otherwise the rain will soak into the wall heads and ultimately ruin them. When cheap, light coping stones are used, it is necessary to lay a sheet of metal (preferably lead or copper) under them, as shown in Fig. 22. The sheet metal is simply laid on the brickwork and bent over about 1 or 2 inches at each edge. The stones are then bedded in place in the usual manner.

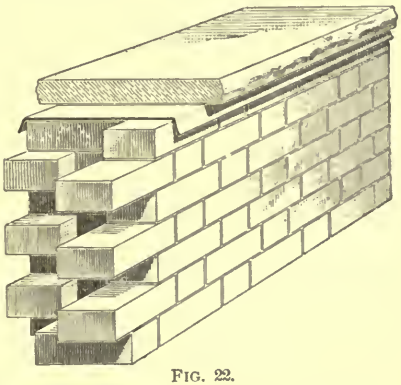


FIG. 22.

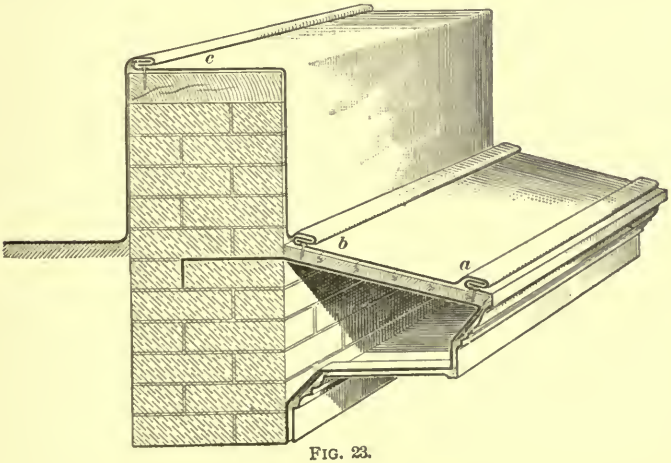


FIG. 23.

35. Coping Blocks.—When coping blocks are used to surmount cornices, the flashing or wash of the crown may be extended through to the back of the wall, where it may connect to the roof covering, or to a gutter lining, as the case may be. When it is necessary, however, to entirely cover the blocking course with the same kind of metal as the cornice, the metal work of the cornice may be extended up and continued over the blocking course, as shown in Fig. 23; the sheets being crimped and held in place by cleats in the seams *a*, *b*, and *c*. A wooden wall cap is placed on top of the brickwork to protect the top course and take the cleat nails.

36. Stone cornices may be flashed as shown in Fig. 24. The copper is bent over the face of the stone and doubled over with a beaded edge on the under side to form a drip. This also prevents the flashing from rising in front. When the top surface is narrow—i. e., less than 12 inches—it does not need to be held down, but when it is wide, the copper should be held down with fastenings, as shown at *a* and *b*.

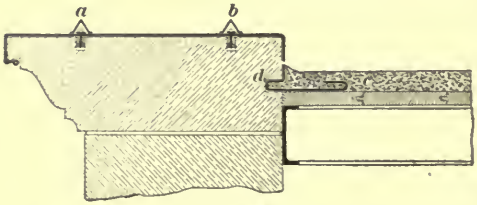


FIG. 24.

The arrangement shown in Fig. 24 is used at the junction between a stone cornice and an asphalt roof laid on fireproof construction, the asphalt covering being shown at *c*. Sometimes the copper is bent down flat over the back of the stone, but the best method of attaching it is to groove the stone at the back and let the copper into it, as shown at *d*. This holds down the flashing at the back.

37. The common method of fastening the sheet to the stone is to drill $\frac{1}{2}$-inch or $\frac{5}{8}$-inch holes at intervals over the surface of the stone. These holes should be cut wider at the bottom than at the top, so that the lead plugs cannot be pulled out. An iron rod, whose diameter is less than that of the screws to

be used, is greased and placed upright in the hole. Molten lead is then poured around the rod until the hole is full. The rod is then pulled out, and when the flashing is all laid and neatly set in place, it is screwed down to the lead plugs with brass screws.

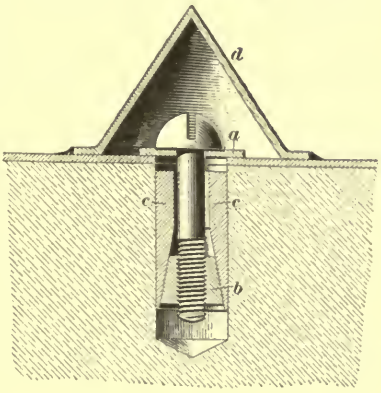


FIG. 25.

Expansion bolts (see Fig. 25) are now generally used for fasteners. After the holes are drilled and the stone covered, the holes are "found" and the expansion bolts are inserted. A washer *a* is placed between the bolt head and the copper, and the bolt is screwed down tight. This draws up the tapered, or wedge-shaped, nut *b* and presses the sides *c*, *c* against the sides of the hole. A cone *d* is then soldered over the fastener, as shown, to make it water-tight. If fasteners are not used, the copper is likely to rattle when the wind blows.

38. Chimney caps are made in different styles. The most simple, and perhaps most common, form is a plain sheet-metal cap which is slipped down over the brickwork about 6 inches, the sides of the cap being nailed into the joints of the brickwork. A superior chimney cap, however, is shown at *a*, Fig. 26. The brick chimney is built up to the course *b*, then the cap is bedded on, and finally the brickwork *c* is filled in

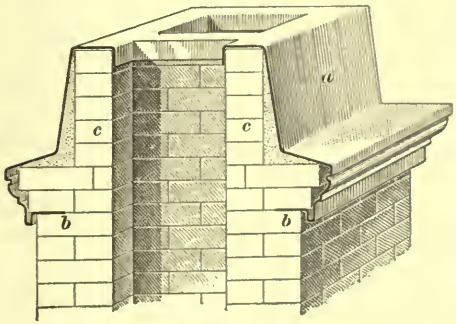


FIG. 26.

from the top, so that its weight on the flange, which is turned over the course *b*, will prevent the cap from being blown off. The moldings of the cap, being of small projection, do not require any lookouts. The brickwork must, however, be built up tight to the top of the cap to prevent it from settling down and flattening the molding.

BALUSTRADES.

39. Balustrades, like cornices, etc., are constructed either with wooden or with fireproof supports; the kind to be employed will depend upon the construction of the building. Balustrades, pedestals, etc. on non-fireproof buildings are usually backed with, or secured to, woodwork, while those on fireproof buildings are nearly always supported by iron or brickwork.

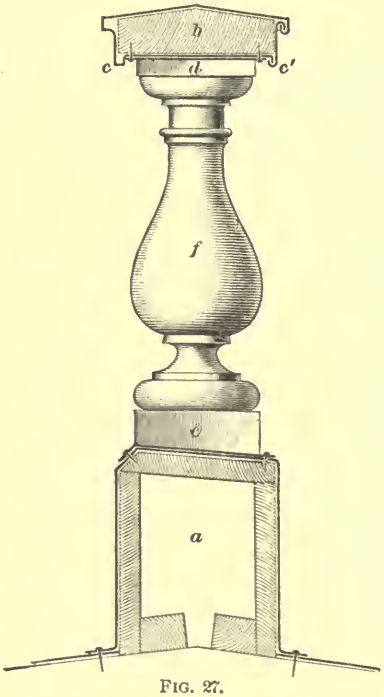


FIG. 27.

Fig. 27 is a section through a balustrade which is commonly employed where the cornice deck pitches to the front and the roof pitches to the rear. The bottom rail *a* extends down to the deck, the metal being flanged over and soldered to the roofing.

When the deck over the cornice grades back towards the balustrade, and when the base rail extends down to the deck, it is necessary to solder in some drain tubes to take away the water. This will prevent a pool of water from forming against the base of the balustrade. The trouble, however, with such tubes is that they will become clogged

with snow, etc. The best arrangement is to elevate the base rail a distance of 2 or 3 inches above the deck. Roof-cornice decks, in fact, should always pitch back to the roof to prevent rain from dripping over the cornice. When the base rail does not extend down to the deck, the sheet-metal backing is composed of solid timber entirely covered with metal.

To prevent the rail from sagging, wooden blocks which are covered with sheet metal are inserted under the rail at distances of from 6 to 8 feet apart. The coverings of these blocks are bent over at the top and nailed to the under side of the base rail, while at the bottom they are bent out and soldered as a flange to the deck.

The cap rail *b* is usually made of wood and covered with two pieces of sheet metal, with drips formed at *c*, *c'*, as shown. The seams are made at the rear.

40. The balusters *f* are either spun, pressed, or cast. If they are spun or cast, there will be no vertical joints in their length. If they are pressed, they are put together in halves, which necessitates two vertical soldered seams. Pressed metal is generally used on ordinary work because it is so much cheaper than the spun or cast metal. The top member *d* and the bottom member *e* of the baluster are usually square. All the different members are securely riveted and soldered together before the baluster is set in position. After the cap and base rails are in place and lined up properly, the balusters, which are hollow and flanged at top and bottom, are pushed into place. The flanges are securely nailed to the under side of *b* and to the top of *a*, as shown, the bottom flange of each baluster being soldered water-tight over the nail heads. The top flanges are not soldered, because the drips protect them.

It is generally understood that sheet-metal balusters are strong enough to support the top rail under ordinary conditions; but in cases where a load is liable to be placed on the cap rail, it is advisable to put a strut inside of each baluster, which will take the load off the metal and prevent the baluster from collapsing.

In fireproof construction the general arrangement is the same, the principal difference being that iron backing is used instead of wood, and the metal is bolted to it in a manner similar to that prescribed for cornices.

41. A **pedestal,** as ordinarily constructed, is composed of a framework made of $3'' \times 4''$ timber, spiked to the

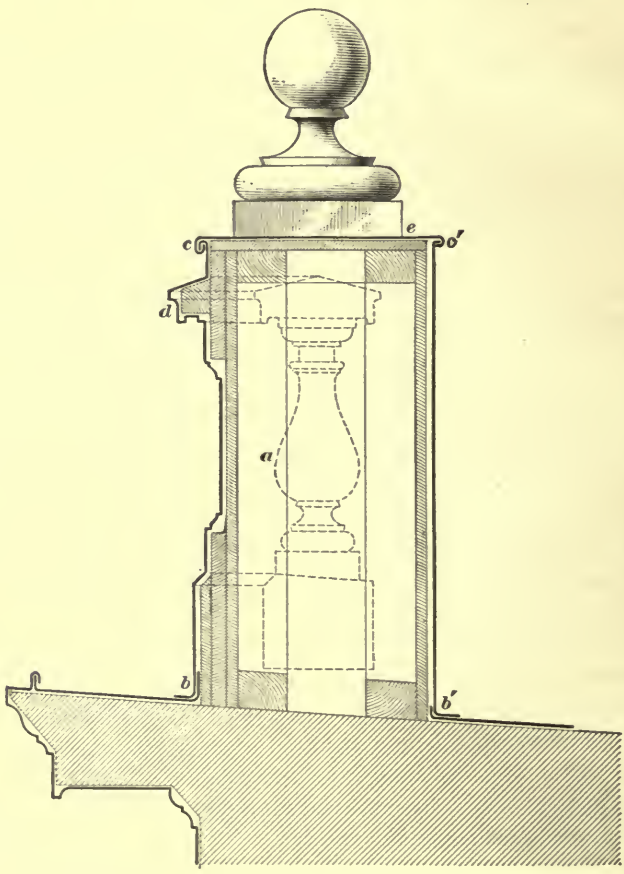


FIG. 28.

roof and sheathed, as shown in Fig. 28. The projections necessary for the moldings, etc. are blocked out. In the

figure the pedestal is provided with a panel face and a flat back. The sides may be paneled or plain. The dotted lines show the relative position of the balusters *a* and the cap and base rails with respect to the pedestals.

The sheet metal for the front and sides is made to fit the pedestal and is then put on in one piece. The back piece is then put in place and double seamed to the sides, flanges *b*, *b'* being formed at the base and soldered to the deck. The top is then put on and double seamed over a flange, as shown at *c*, *c'*. The double seam is shown turned down and finished at *c*, while it is only half finished at *c'*. The molding, or projection at *d*, is returned on the pedestal and miters with the top rail. The base block, in a like manner, returns and miters with the base rail of the balustrade. If a finial or vase is to be set on the pedestal, the connection should be made with a flange at *e* and should be lock seamed and soldered water-tight.

Corner pedestals are paneled on two sides; this necessitates a vertical seam on the outside and inside corners of the pedestal.

In fireproof construction, the backing for the pedestals is usually composed of brickwork when they are located immediately over the wall head. The sheet-metal covering is then made up in one piece and is slipped down over the brickwork, being secured to the deck with a flanged seam, as shown in Fig. 28. The top sheet, also, is secured in a manner similar to that shown in Fig. 28.

When a tall finial, which requires a support, has to be set, it is advisable to run a tube up through the center of the pedestal and screw the top member of the finial to this support.

When a solid brick backing cannot be obtained, it is necessary to construct a framework of wrought iron, which is thoroughly braced diagonally and bolted to the roof. The metal covering is then placed around the frame, and bolted or riveted in position in the ordinary manner.

GUTTERS.

42. The varieties of gutters that will be treated of in this section are: *eaves* gutters, *roof* gutters, *parapet* gutters, and *belt-course* gutters of various materials and for various classes of buildings. A little has already been said about valleys, flanks, and other sheet-metal roof work in *Carpentry*, and need not be repeated in this section.

An eaves gutter of the simplest kind, is shown in Fig. 29; it is known as a *half-round hanging*, or *trough*, gutter, and is commonly used on ordinary frame buildings. The standard widths are 3, 4, and 5 inches measured across the top of the inside. The bead is about $\frac{1}{2}$ inch in diameter and is turned outwards. These gutters are suspended from the eaves with adjustable malleable-iron hangers set at about 3 feet centers. When they are secured to shingle roofs, the hangers may be simply nailed or screwed on to the shingles as shown in Fig. 29. A better method, however, is shown in Fig. 30, where the hangers are firmly nailed to the roof-boarding before the shingles or slates are laid.

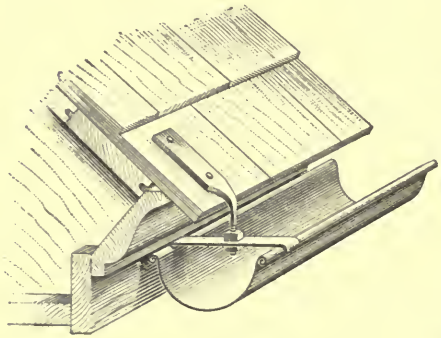


FIG. 29.

The pitch or grade of hanging gutters should not be less than 1 inch in 8 feet and the gutters should be hung low enough to allow the snow to slide over them. Three-inch gutters are useful only for porches, bay windows, and other small roofs. The 4-inch size should be used on the main roof when the horizontal or projected area does not exceed 500 square feet. The 5-inch size is used chiefly on factories, warehouses and at the rear of large city buildings, where the projected area does not exceed 1,500 square feet. Hanging

gutters of this class should be used only when the eaves overhang the wall.

When a hanging gutter is attached close to the wall, the back of the gutter is extended up under the shingles or slates at least 6 inches, as shown in Fig. 30, the object being to prevent heavy winds from blowing the rain drops against the siding. The gutter is held up in front by tension straps *a*, *a*. The lower ends of the straps are soldered to the bead,

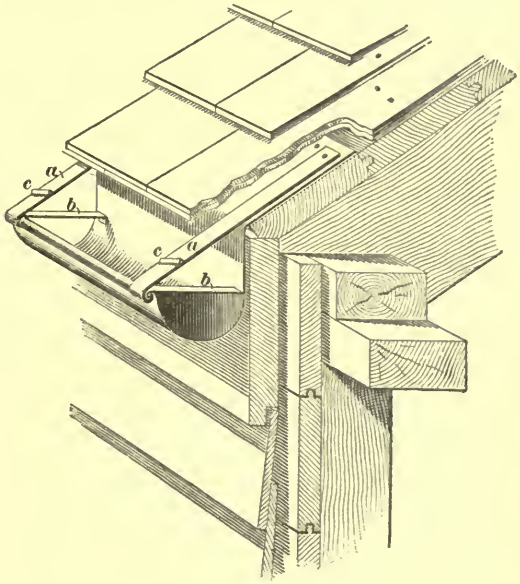


FIG. 30.

and the upper ends are nailed to the roof. Braces *b*, *b* are soldered inside, and above the water line, to prevent the gutter from collapsing and sagging. Small clips *c*, *c* are soldered on the straps at an angle, to divert any current of water which may flow along the strap and thus escape over the edge of the gutter. This gutter should be graded about the same as that shown in Fig. 29.

43. Molded Eaves Gutters.—Molded, i. e., ornamental, eaves gutters are often attached to buildings in a manner

very similar to that shown in Fig. 30, but while the gutter in this figure is laid with a pitch, such molded gutters are laid perfectly horizontal. In this respect they are defective, because all gutters should pitch down to the outlet pipes. In good practice, it is advisable not to run a gutter with a horizontal bottom, not only because the gutter is liable to overflow during heavy rain storms, but because a pool of water will remain in the bed of the gutter after the rain has ceased. To prevent an overflow, it is necessary to make molded eaves gutters quite large; and to properly drain them, it is necessary in some cases to install a false bottom which will grade down to the point of outlet with a suitable pitch.

When the gutters are made of iron, they should always be graded in order to prevent deposits of mud, which hasten corrosion.

44. Fig. 31 shows a copper molded eaves gutter set on the top of a brick wall of a fireproof building, which is provided with a terra-cotta roof. The bed of the gutter

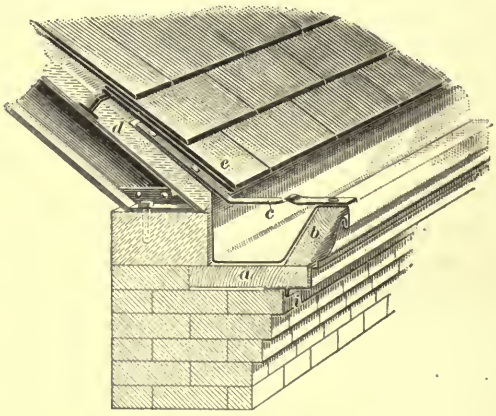


FIG. 31.

rests on a board *a* which is inclined, to give the proper pitch. The face of the gutter forms a continuous horizontal molding and is made from cold-rolled sheet copper. The front

edge of the gutter lining is bent down over the face and is lock seamed to the copper molding as shown.

The back of the gutter is extended up over the terra-cotta slabs *d* and under the slates *e*. A series of brass straps *c* are spaced off along the gutter and secured at distances of not more than 3 feet, being bolted to the plank *b* in front with brass lagscrews. The rear end of each strap is run up under the slates and bolted through the terra-cotta slabs with brass bolts of proper length, large brass washers or plates being used under the slabs to prevent the nuts from sinking into them. Each strap is twisted one-half of a turn, as shown, to prevent roof water from working over the face of the gutter. The sheet copper is doubled and pinched at *i* to form a drip. In cold climates it is advisable to slope the back of the gutter, the space behind being thoroughly filled in solid. This will prevent the gutter from bursting with the formation of ice, if the conductor pipe should choke and the gutter fill with water.

45. Roof Gutters.—Fig. 32 shows a simple form of roof

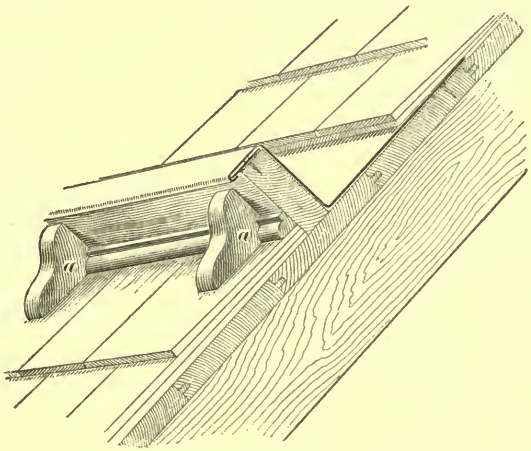


FIG. 32.

gutter. It consists of a board nailed to the roof and braced by brackets *a*, *a*. The board is laid on an incline to form the

proper grade, and the lining, which is usually bright tin or terne plate, is continued up under the shingles, and nailed down. The front edge is doubled over a strip of metal which has previously been closely nailed to the woodwork. This is called a *blind edge*.

The necessary incline of this gutter spoils its appearance; to form a roof gutter which will appear parallel with the roof, it is necessary to build it in a manner similar to that shown in Fig. 33. A tapering gutter strip *a*,

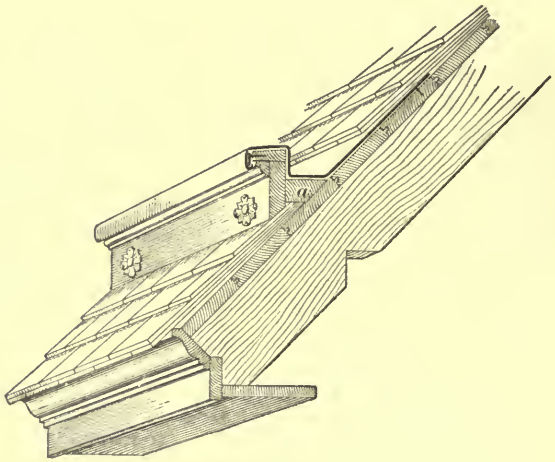


FIG. 33.

usually 2 inches thick, is laid to run the whole length of the gutter, and grades the bottom in a proper manner. These gutters really form snow boards, and during winter often become so clogged with snow that the water from melting snow cannot run off the roof freely, but is forced to pass through between the shingles or slates and thus cause a temporary leakage. For this reason, they are not to be recommended.

46. Cornice Gutters.—The cornice of a building very often does duty as a gutter also.

A wooden cornice gutter, sometimes called a *box*

gutter, as shown in Fig. 34, is employed in the construction of the better class of framed buildings. The carpenter completes the cornice and forms the bottom of the gutter with the proper grade. The tinsmith then lines the gutter before the shingles or slates are laid. The lining, like those in Figs. 32 and 33, is nailed to the roof and over the front edge of the gutter with a blind edge, as shown.

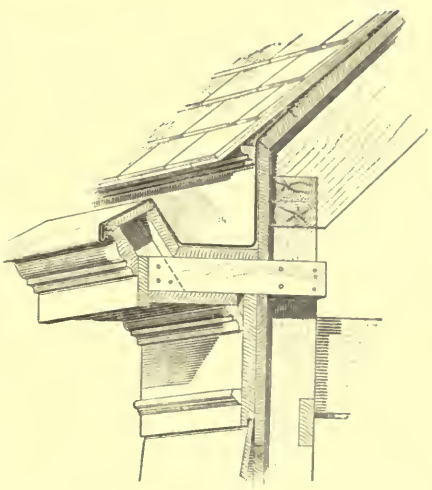


FIG. 34.

Sheet-metal cornice gutters are constructed on the same general principle.

47. Terra-Cotta Cornice Gutters. — This kind of a gutter, for a fireproof building, is shown in Fig. 35. The

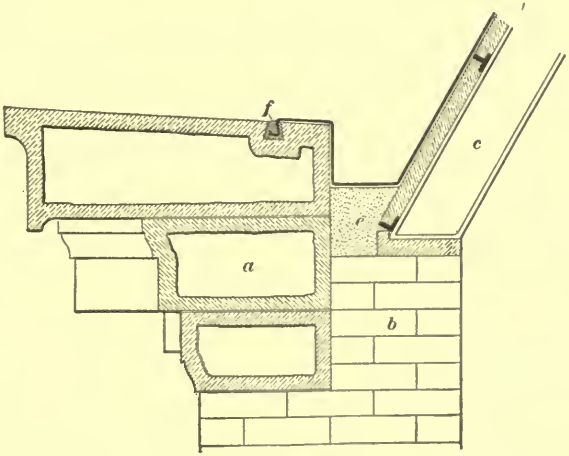


FIG. 35.

terra-cotta slab *a* of the cornice is backed by brickwork *b*, upon which rest the I beams *c* of the roof trusses. The usual angle or T iron purlins support the porous terra-cotta slabs. The mason fills in the gutter bed *e* with cement concrete and grades it to the proper pitch. The sheet metal, which is generally 16 or 18 ounce soft or hot rolled copper, is then bent up and laid into the gutter, the front edge being bent down into a groove *f*, which is molded in the terra cotta, and the back edge is run up the roof and overlapped by the slates or tiles in the usual manner. The connection between the copper and the terra cotta is made water-tight by filling the groove full of molten lead, which, when cold, is solidly batted with a hammer and calking tools. If this method of attachment is not desired, the cornice may be molded with a dovetailed projection, so that the metal may be sprung over it as shown in Fig. 36. This will hold the copper down, but it is not as solid as the calked joint shown in Fig. 35.

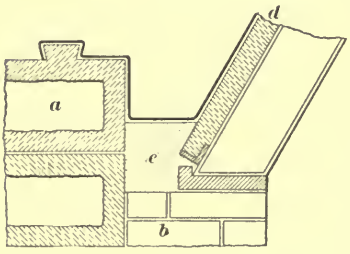


FIG. 36.

48. Parapet Gutters.—A parapet gutter for a building of modern fireproof construction is shown in Fig. 37. The only notable difference between this and the other box gutters, already described, is the fact that the gutter is located behind a wall which is higher than the point to which the gutter is extended under the slates. It will be readily seen that there is great danger of the building being flooded if the leader opening should become covered with leaves or dirt, so that the rain water cannot escape down the conductor pipe *a* as fast as it flows into the gutter. To avoid this difficulty an **overflow tube** *b* having a sectional area at least equal to, but preferably greater than, that of the conductor pipe, should extend through the wall as shown.

The bottom of the overflow opening should not be less than 5 inches above the lowest point of the gutter bed, but

not high enough to cause the water to overflow any upstands or flashings that the gutter may be provided with. In the figure, the sheet copper composing the gutter and the rear covering of the parapet wall is all in one piece, consequently,

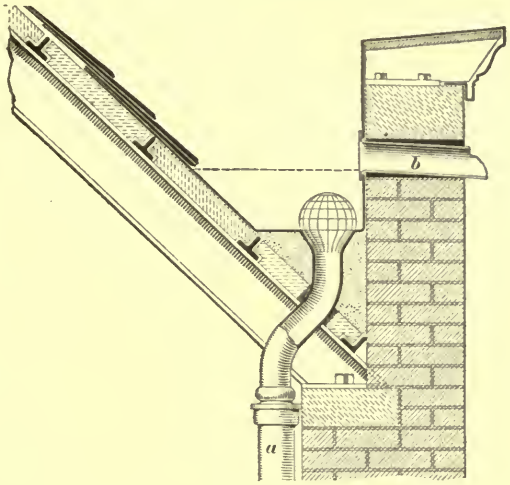


FIG. 37.

the main consideration in locating the overflow tube here is to prevent the water from backing up under the slates and leaking over the top edge of the flashing. The sill of this gutter, like that shown in Fig. 35, is filled in with cement and graded down to the conductor opening.

When the parapet wall is extended higher than about 18 inches or 2 feet above the gutter, it is customary to flash the back into the wall, as shown at *a*, in Fig. 38. A joint in the brickwork is raked out to a distance of about $1\frac{1}{2}$ inches, and the copper is bent over and let in as shown. Soft cast-lead bats *b*, *b* are then driven solidly into the raglet, about 6 or 8 inches apart, and the raglet is then filled with elastic

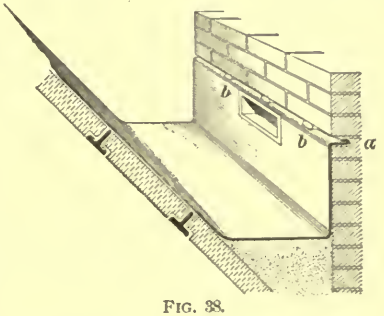


FIG. 38.

cement. The objection to this arrangement, however, is that the expansion and contraction of the gutter is likely to loosen the bats, and the raglet joint may leak.

49. A better arrangement is shown in Fig. 39, in which the gutter is not nailed down or secured at any point except at the conductor opening. The upstand *a* back of the parapet is held down by a number of **cleats** *b*, of which the tops are doubled over the top of the upstand and the lower ends are bedded in the cement sill. A counterflashing *c* of lead or copper is batted into the raglet and overlaps the upstand at least 3 inches. The top of the overflow tube *d* should be on a line with the top of the upstand or a little below it. To avoid nailing down the gutter at the back, also to prevent it from rising or shifting, an iron or brass **tilting fillet** *e* is bolted to the fireproof roofing. The sheet copper is bent under and doubled over this fillet, as shown. The tilting fillet is also advantageous to the slater, because it enables him to start his bottom course with the proper cant.

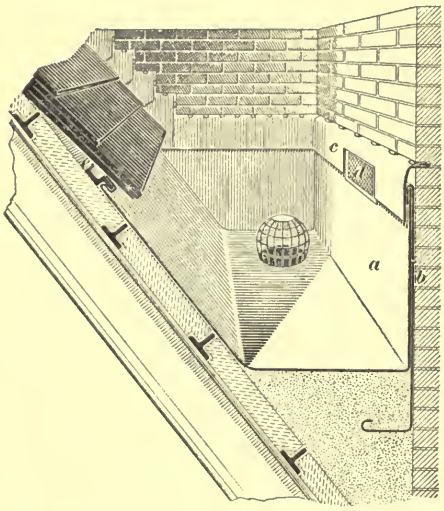


FIG. 39.

50. **Wood Tilting Fillets.**—These fillets are used when the roof is covered with boards. The fillet is shaped as shown at *a*, Fig. 40, and extends the full length of the gutter. A number of strong cleats *b* are nailed to the roof and bent over the fillet. The gutter is then laid and the cleats are doubled back over the edge, as shown. This is considered

first-class practice. The method of laying slates or shingles flat on sheet-metal gutters, valleys, flanks, or other flashings

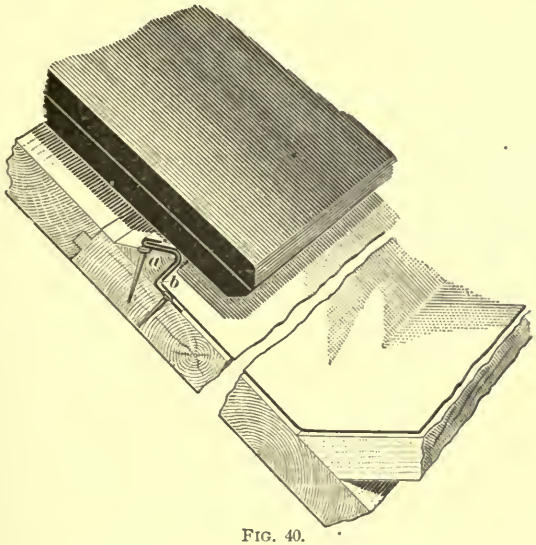


FIG. 40.

should never be followed. Water will work up between them by capillary attraction.

51. Corbel-Table Gutter.—A corbel-table gutter is shown in Fig. 41. It is supposed to form a belt all around the building, being located about 4 or 5 feet below the eaves. Such gutters, being so far below the eaves, do not carry much water at any time; they simply serve to carry off the drip. The greater part of the water shed by the roof during heavy showers, shoots over the gutter, this action being most pronounced when the roof covering is of a corrugated character.

A corbel table *a*, which rests on corbels *b*, *b*, forms a support for the gutter. The lookouts *c* are made of cast iron and are set at about 2 feet centers all along the table, their prongs being let into the mortar joint at the back about 2 inches. The crown molding and its wash are made of copper, the lower edge being lapped about 4 inches over the top

of *a*. The top edge is secured by cleats to an iron bar. Another iron strap, or bar, at *e* runs the full length of the gutter, and the copper is secured to it with brass bolts. When the molding is in position and properly lined up, the

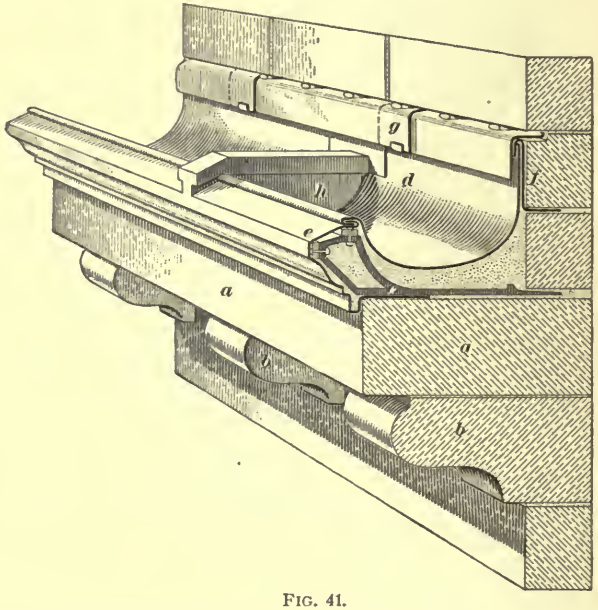


FIG. 41.

mason fills in the gutter with cement to form a curved bottom with the proper grade. Strong cold-rolled copper cleats *f* are secured to the wall to hold down the back of the gutter *d*; the front edge is double seamed and soldered as shown. The back is counterflashed in the ordinary manner. If the counterflashing is of lead, the top joints *g* should be locked into one another at the lower edge, as shown, to prevent the wind from raising the corners.

52. When such gutters are long, some provision must be made for expansion and contraction, otherwise they will soon tear apart and leak. In Fig. 41 this is accomplished by introducing a **saddleback** joint at *h*, a cross-section of which is shown in Fig. 42. A plank *i*, 2 inches thick, which

has been previously soaked in oil or asphalt, is set on edge and bedded in the concrete. If the gutters are laid during hot weather the upstands *j*, *j* should be fitted to almost touch the plank, so that during winter, when the gutter becomes intensely cold and contracts, the upstands will be drawn away from the board and take the position shown by the dotted lines. This forms an expansion joint of the best type. The cap, being short, is nailed to the wood and the nail heads are covered with a copper disk, which is soldered water-tight around the edge.

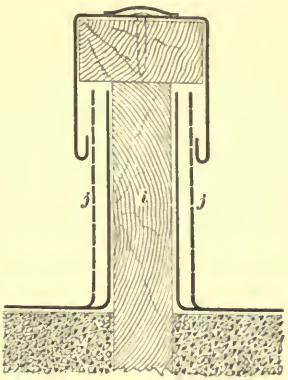


FIG. 42.

CONDUCTORS.

53. Conductors, or *leaders*, as they are often called, are the pipes which conduct or lead away the water from the gutters. They may be classed as *inside* or *outside* leaders. Inside leaders will be treated in *Plumbing and Gas-Fitting*.

54. Outside Leaders.—Outside leaders are fitted up against the outside of the building. They are made in many shapes and of different metals. Fig. 43 shows the *round-pipe* leader as usually erected. These leaders are usually made of tin by the tinsmith, who also makes the elbows *a*, *a*, *a*, which, usually, are altogether too sharp. Tin straps *b*, *b* are soldered to the leader at intervals of about 6 or 8 feet and are nailed to the walls, as shown. Round leaders are not suitable for outside service in cold climates because they persistently freeze and burst.

Fig. 43 illustrates an ever recurring spectacle in cold weather, when snow lies on the roof, and the temperature of the air is below freezing point. The sun shines

on the roof, but not on the leader. The snow on the roof melts and the water trickles down the leader, and, by the time it nearly reaches the bottom, it becomes frozen to the sides of the leader. This ice slowly thickens until the leader is entirely choked at that point which, in Fig. 43, is the lowest elbow.

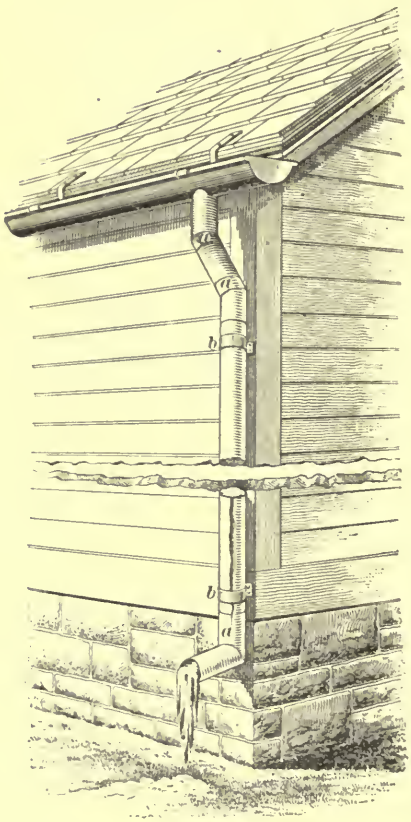


FIG. 43.

The remainder of the melted snow then gathers in the leader and fills it. This water now solidifies and bursts the leader as shown. The pipe has burst because it could not stretch enough to accommodate the increase in volume of the water as it was changed into ice.

55. Expanding Pipes.—Expanding pipes should be used to overcome the trouble from frost. A common form, shown in Fig. 44, is simply a corrugated round pipe. The corrugations allow the pipe to increase enough in diameter to compensate for the formation of ice inside, without bursting the pipe. If the pipe is frozen repeatedly it will ultimately burst, because it takes a permanent set every time it is thus expanded. These pipes are usually made of galvanized iron or cold-rolled copper, in 8 or 10 foot lengths.

56. Square or Rectangular Leaders.—These leaders are made of crimped or corrugated sheet metal, and are often

used to obtain a more ornamental effect than is produced by round leaders. They should be supported by ornamental bands in a manner very similar to the plain straps shown in Fig. 43, the straps being made so that the leaders will hug the wall. If the walls are built of masonry or brickwork, it is necessary to drill holes at the back of the bands, then drive soft-pine plugs into the holes and cut them flush with the face of the wall for the purpose of receiving the spikes; for good work expansion bolts should be used.

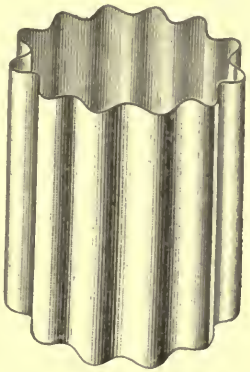


FIG. 44.

In climates where there is no danger of outside leaders being frozen, the best method of attaching rectangular leaders in a neat and strong manner to brick, stone, or terra-cotta walls, is shown in elevation at (*a*) and in section at (*b*), Fig. 45. Two copper beads *a*, *a* are soldered around the top edge of each leader and a cast-copper band *b*, provided with ornamental lugs, clasps the top of the leader against the building. The lugs are secured to the walls with expansion bolts, as shown by dotted lines at *c*. The leaders are connected together by slip joints as shown in the section. Each band thus supports a section of the leader, which should not exceed 8 feet in length. This arrangement allows each section to expand and contract freely; if all the joints are soldered together, the leader is

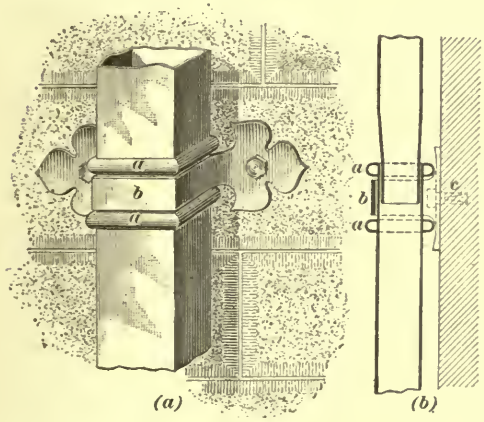


FIG. 45.

formed into one long, rigid line, which soon becomes loosened by expansion and contraction. These leaders should be made with the crimps running across them, not lengthwise, so as to secure a very neat, flat, and stiff surface.

Beaded tops and cast bands are not adapted for outside leaders in cold climates, because the beads and the bands are not pliable enough to resist the action of frost. The best attachment for such climates is composed of a brass or copper eye, which is riveted and soldered securely to the back of the top end of each section of the leader. These eyes are bolted to bronze hooks which are secured to the wall. An ornamental stamped sheet-copper band is then slipped on between the heads to conceal the real rigid attachment. The lugs of the band should be attached to the wall by expansion bolts. This arrangement gives a pliable joint. The corrugations in this leader, however, must run lengthwise, and all the joints should be slip joints. Iron supports should never be used in or against a stone wall, because they rust and stain the masonry.

57. Offsets in leaders should always be avoided. It is common practice to offset the leaders at stone, brick, and terra-cotta moldings, but in good practice they should be fitted up straight and plumb, the necessary holes being cut through special blocks formed in the molded courses for the passage of the leaders. It is customary to discharge sheet-metal leaders into a cast-iron pipe which is continued up about 4 or 5 feet above the surface of the ground, the object being to prevent the leader from being flattened or otherwise injured. Rectangular leaders should, for the sake of appearance, connect at the bottom with a rectangular cast-iron pipe, and not with a round pipe.

58. Size of Leaders.—The proper size of leaders, of course, will vary with the climate, the amount of rainfall, and the manner in which the gutter catches the water; but a good safe rule for every-day practice is to allow 1 square inch of sectional area of conductor pipe for every 75 square feet of flat roof area. No leaders, however, should be less

than 2 inches in diameter, and even this size should be used only for small roofs, such as those over bay windows, small porches, etc.

The *underground pipe* (often drain tile), into which the leaders discharge, should not be less than 4 inches, inside diameter, and they need not be more than 8 inches in diameter for any work where the roof area is less than 1 acre. In measuring the watershed of pitched roofs, calculate the projected or horizontal area—i. e., the area on the plan.

59. Rain-water heads, sometimes called *conductor heads*, are often employed on the top of a leader, and treated as an architectural feature by forming a graceful outline to the receptacle for the gutter discharge. Two or more leaders may deliver into one head, as the conditions may require.

Fig. 46 shows a conductor head in section. It is set on top of a rectangular corrugated sheet-metal leader *a*, which should be securely fastened to the wall by a band on top. The lower end of the head slips into the conductor, and the top is secured against the stone wall with expansion bolts or other fasteners. A brass angle should be fitted inside the rim. The roof gutter empties into the head through a large lead or copper pipe *b*, which runs up a chase in the back of the wall, thus concealing it from outward view. The top of the head should be covered to prevent birds from building their nests in it, or in the pipe *b*.

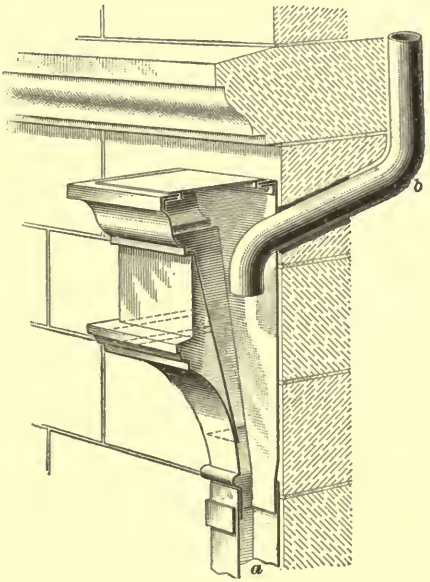


FIG. 46.

The proper position for a rain-water head should be carefully shown on the elevation, as mechanics are prone to set them at the handiest place, without reference to the architectural treatment of the facade. All rain-water heads should be lined inside with a tapering box to extend below all moldings and prevent possible leakage, and also to prevent noise during heavy rains.

60. Strainers.—Every leader opening in a gutter must be provided with a strainer to hold back leaves, twigs, etc., and to prevent birds from building nests in the leaders. The best strainers are those constructed of a ball or hemispherical form, like those shown in Figs. 37 and 39.

For ordinary purposes, where the roof water flows to waste, wire ball strainers, put together something like bird cages, are generally used. But in cases where the roof water is gathered into cisterns or tanks, and stored there for domestic use, the strainers must be very close in order to prevent pieces of leaves, etc. from being washed down into the cisterns. Such vegetable matter soon decays and pollutes the water. The strainer *b*, in Fig. 47, is specially made for this service. It has a very large straining area, which is closely perforated with holes not larger than $\frac{1}{8}$ inch.

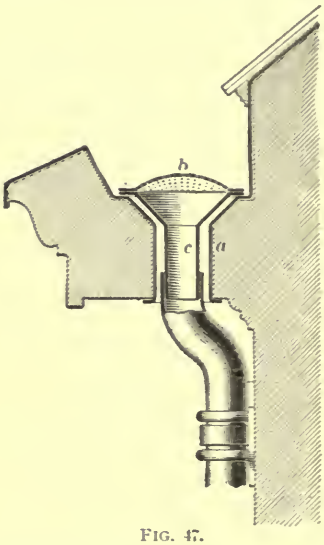


FIG. 47.

61. Gutter connections to leader pipes are very important details and should be carefully considered. The offsets necessary for cornice and overhanging gutters should have a good grade from gutter to leader, and should be composed of easy bends—not sharp elbows. Owing to the fact that leaders are liable to freeze, it is advisable to provide outside gutter connections with a slip tube,

as shown at *a*, Fig. 47. This tube is soldered to the gutter lining on top, and is flanged over the face of the soffit of the cornice at the bottom, and thus forms a water-tight channel through which the leader pipe passes. If the leader should freeze and burst between the gutter lining and the soffit of the cornice, this tube will prevent the water from leaking. In the event of the cornice being made of woodwork, such a leak would soon cause the decay of the material.

When copper leaders connect with tin-lined gutters, or vice versa, an **insulation joint** should be made at a convenient point to prevent a too rapid destruction of the metal by galvanic action. Thus, in Fig. 47, a slip joint should be made at *c*, with a sleeve of tarred or painted burlap inserted between the gutter tube and the leader pipe.

62. Leader Cut-Off.—When the leaders discharge into cisterns or tanks, it is advisable in all cases to provide them with cut-offs, so that the water may be discharged to waste or into the cisterns, as desired. Every roof is foul, to a certain extent, with decaying vegetation, bird lime, etc., and all this matter is washed off during the first few minutes of a rain storm. If a cut-off is not used, the dirt, of course, goes into the cistern. It is customary to leave the cut-off free for rain to flow to waste until the roof is supposed to be washed clean, then it is turned so that the remainder of the water will flow into the cistern.

There are many different kinds of cut-offs on the market. Some are made to be operated by hand, while others are intended to operate automatically, when a certain volume of rain water has passed through to waste. The latter are preferable, if reliable, because the hand cut-off is likely to be neglected.

DOMES AND LANTERNS.

63. In many parts of Europe it is customary to cover domes, lanterns, cupolas, etc. with sheet lead; but owing to the great variations in temperature which are encountered in the United States of America, it is necessary to use a

metal which is better adapted to withstand the unavoidable expansion and contraction.

Sheet copper or galvanized iron are the best metals for use in countries where excessive changes in temperature occur. The latter, however, is not durable enough for covering domes, lanterns, or cupolas, and, consequently, sheet copper is generally employed.

There are different methods of covering domes, but the following four may be considered preferable: namely, *plain* or *smooth*, *ribbed*, *paneled*, and *metallic shingle* or *slate* coverings.

64. Smooth covering is usually put on domes in a manner similar to that employed in flat-roof covering, with flat locked seams, each sheet being well tied down with strong cold-rolled copper cleats. If the dome is large the ordinary flat sheets about 20 in. × 28 in. are generally used, the curvature of the dome being so slight that the soft copper will easily adapt itself to the shape. When the dome is small, however, each sheet must be blocked out to the proper curve, so that the covering, when finished, will have a neat, smooth appearance and be free from buckles. The chief objection to locked-seam covering is the liability to leakage, chiefly through the seams, on the nearly horizontal parts of the dome. The solder will spoil the appearance of the dome if the copper work is allowed to retain its natural color.

65. Ribbed Surface Covering.—To avoid leakage on domes by the effects of expansion and contraction, and to prevent any solder from discoloring the copper work, some form of ribbed covering is employed. This requires the use of a standing or a roll seam, as the character of the building may demand.

The space between the standing seams or rolls should not be more than 2 feet wide, and the sheets should not be more than 4 feet long. They must be securely supported from the top edge, preferably with heavy cold-rolled copper cleats.

It is advisable in all first-class sheet-metal roofing to avoid driving nails through the sheets at any point. The

sheets are thus permitted to freely expand and contract without tearing the metal.

An excellent roll seam is shown in Fig. 48. The batten, or roll strip *a* is nailed down over a long cleat strip *b*. The sheets *c*, *c* are then sprung in between the rolls, and the cleat strip is doubled over the upstand. The roll cap *d* is then put on over the roll, and locked into the cleated upstand as shown. The roofing sheets, cleat strips, and roll caps are thus all locked together and made water-tight, and yet are free to expand and contract individually. The batten nails combined with the outward curvature, which the sheets *c* must necessarily have, will prevent a gale from rattling or loosening the sheets.

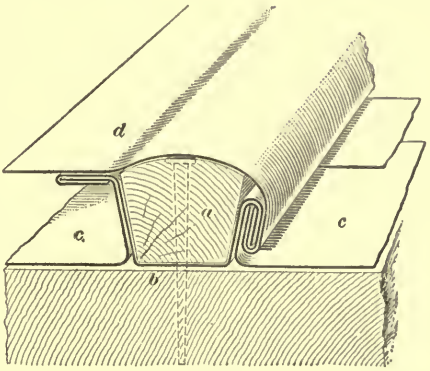


FIG. 48.

66. Horizontal Seams.—The best form of horizontal seam that can be made on domes is shown in Fig. 49. A strong cold-rolled copper cleat strip *a* is nailed to the roof with flat-head brass or copper nails; and the top edge of the under sheet, the bottom edge of the upper sheet, and the cleat strip are all locked together as shown. With this arrangement, each sheet

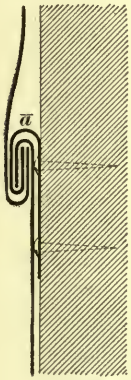


FIG. 49.

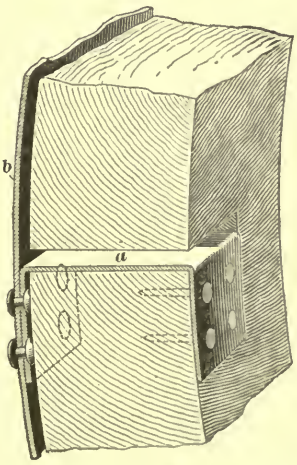


FIG. 50.

can expand and contract lengthwise without affecting the stability of the support. If the sheets are simply lapped at this seam, the wind will get underneath and raise them in the middle, thus opening the seams and making them visible from the street.

When it is required to set the rolls more than 2 feet apart, it becomes necessary to support the sheets between the rolls. This is accomplished in different ways. The sheets may be laid so that the horizontal locked seams will be about 18 or 20 inches apart, the rolls being perhaps 4 or 5 feet apart. When very large sheets must be used, however, *secret tacks* *a*, Fig. 50, are riveted and soldered to the back of the sheet *b* at intervals, which will allow about 2 or 3 square feet to be supported by each tack. As the sheets are being put on, the tacks are pushed into long, narrow holes in the woodwork, and then pulled through and nailed to the inside of the dome as shown.

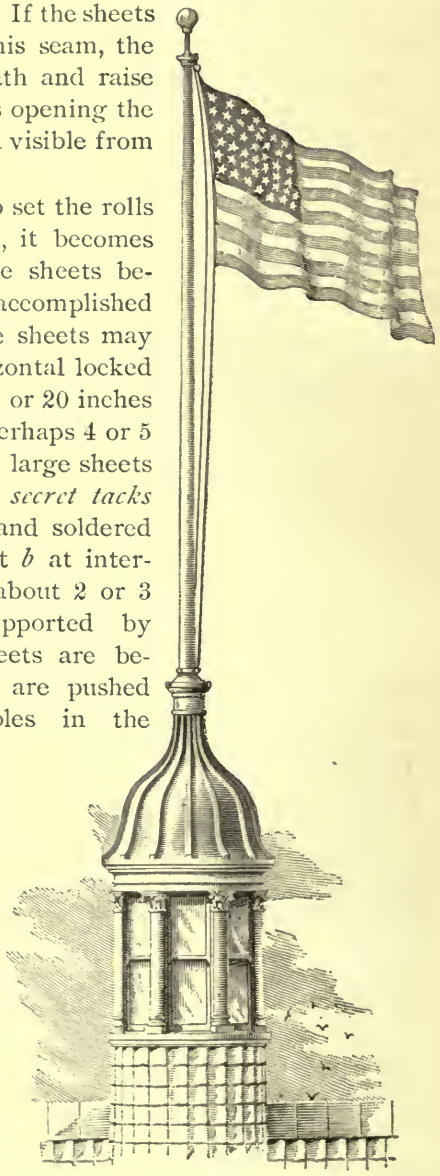


FIG. 51.

67. Location of Rolls.—In locating the position of the rolls it is necessary to consider the general construction of the edifice, both above and below the dome. The ribs or rolls should not be put up

to suit the standard stock sizes of copper sheets, but they must be located to harmonize with the leading architectural features of the composition.

For example, consider the dome of the cupola, or lantern, shown in Fig. 51. The ribs here divide the dome surface into equal sections, two sections being immediately over each window opening. Every second rib is directly in line with the center line of a column. When the sheets are drawn closely together at the top, as shown, the ribs are usually tapered, being wider at the bottom than at the top, but when there is considerable space between the top ends of the ribs, they are usually made the same width throughout their length.

68. Paneled Dome.—A paneled dome is shown in elevation in Fig. 52. The lantern under the dome is octagonal in form, with a window *a* in each side. The dome, however, is round in plan with a panel *b* located directly over each window. The top of the dome is surmounted by a statue, the base of which is shown at *c*. A vertical section through the dome and a few details are shown in Fig. 53. The elevation, Fig. 52, shows ribs *d*, *d* running from the cornice of the lantern up to the base of the statue, but these may be omitted.

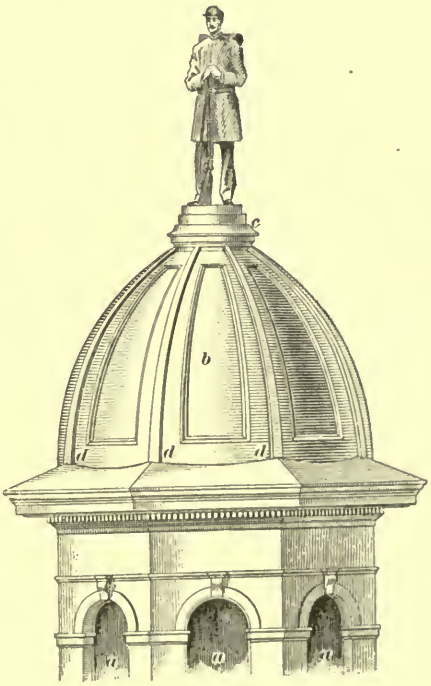


FIG. 52.

At *e* in the detail (*a*),

Fig. 53, is shown a method of securing the panels in place without ribs, when there is no panel molding. The panels are simply double seamed with cleat strips to the stile strip *c* as shown. But where ribs are desired on the stiles, or when moldings must be run around the panels, the con-

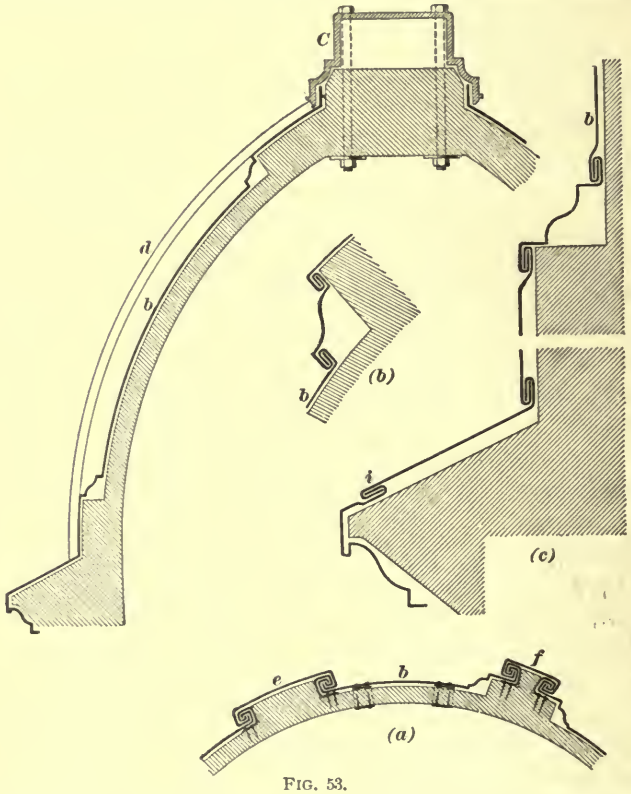


Fig. 53.

nections may be made as shown at *f* in the same detail. If the panels have a larger surface than 3 or 4 square feet, secret tacks may be employed to advantage, as shown by dotted lines. A detail of the top molding of each panel is shown at (*b*), and a detail of the bottom and the wash over the corona of the lantern is shown at (*c*). These seams are all made in the shop, being locked and thoroughly soldered at the back, with the exception of *i*, which is made in place

and is thoroughly cleated and soldered. The statue base is slipped down over a sheet-copper collar, and is secured to the top of the dome with four bronze bolts, which are threaded close under the head to make a permanent water-tight connection. Fish-plates and nuts are employed underneath in the ordinary manner.

69. Flagpole Flashings.—These flashings, and those around all other forms of movable finials, require much attention to detail, as they must be made water-tight, and remain water-tight under peculiar conditions. Every flagpole sways more or less, according to its strength, the pressure of the wind, etc., and, therefore, a rigid flashing at its base cannot be durable. The liability of the pole to "settle down" is another item to be considered. On this account it is advisable to use **slip joints** or telescope flashings, which are provided with enough clear space or "play" to allow the pole to move or sway in any direction without touching or affecting the sheet-metal covering of the dome. A good arrangement is shown in Fig. 54, which is, in fact, a detail of the intersection between the flagpole and the cupola shown in Fig. 51. The rolls of the dome finish inside of the bead *a*. The copper work finishes around the top member *b*. An 8-pound per square foot sheet-lead bonnet *c* encircles the pole and covers the member *b*. The top of the bonnet is "dressed" close into a small groove in the pole, which is cut just deep enough to allow the lead to finish flush, a bed of red and white lead being used to make the connection water-tight. The bonnet is nailed to the

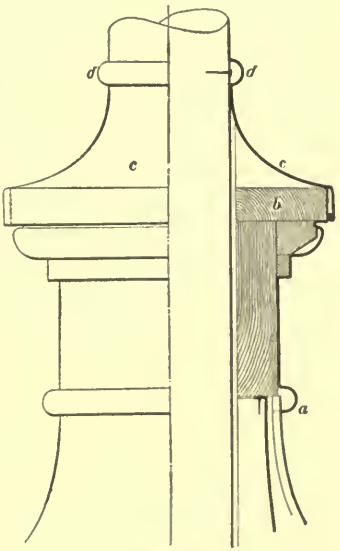


FIG. 54.

pole with a ring of 1-inch, pointed, flat-head copper nails, which may be concealed with a bead *d* if desired. The lower edge of the bonnet overhangs the block *b* and forms an open lap joint around the top of the copper. The top of the block *b* is well greased, and the bonnet is free to slide as the pole sways.

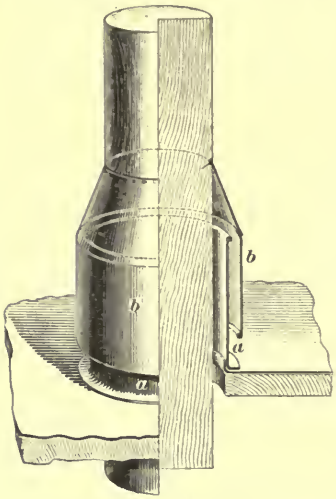


FIG. 55.

When the pole intersects a flat roof, a plain slip-joint connection, like that shown in Fig. 55, may be used. A cylinder, or upstand, *a* is soldered to the roof. A sleeve *b* overhangs the upstand and is nailed to the pole as shown, a space being provided on each side of the upstand to allow the pole and its flashings to move in any direction.

70. Flagpole Cap.—The top of a pole should always be protected either by a sheet-metal flashing or by a cap. A flagpole cap, with regulation ball, is shown in Fig. 56, which is a detail of the cap shown in Fig. 51. A brass casting *a* fits snugly over the top of the pole and is secured to it with brass screws. An eyebolt at the left holds the flag pulley. A piece of brass tube *b* joins the cap to a brass spud *c* which is soldered to a seamless copper ball.

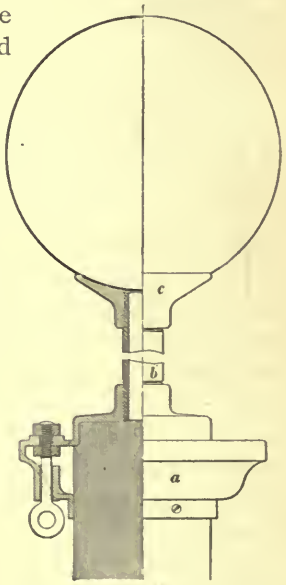


FIG. 56.

This style of cap not only protects the pole from the weather, but provides a suitable pulley connection, and gives an artistic treatment to the apex of the flagpole.

CRESTINGS.

71. Sheet-metal crestings are of varied design and construction. They can, in fact, be made in any design which is adapted to stone or terra cotta.

The most important features to consider in crestings are the method of support and the connection to a slate or shingle roof. Ordinary crestings are so constructed that the nail heads in the top course of slates are exposed to the weather. This is a mistake, as the rain will certainly follow the nails and cause slight leakage, which may not be visible, but which, nevertheless, hastens the decay of the timber and rusts the nails.

72. Attachment.—Fig. 57 shows a method of attaching sheet-metal cresting on ridges and hips in such a manner that

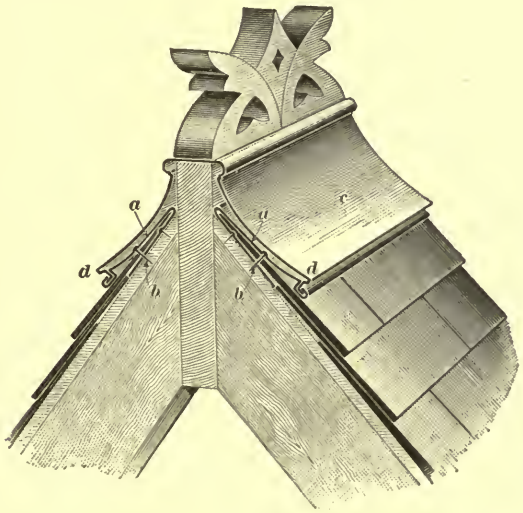


FIG. 57.

the nail heads are all concealed. Channel strips *a*, *a* of strong sheet metal are bent to the shape shown and nailed on the roof close to the ridge pole. The top course of slates is then pushed in the channel and secured with the nails *b*, *b*, which are driven through two thicknesses of slate and two

thicknesses of sheet metal. The cresting *c* is then sprung over the channel strips and the lower edges are closed into them, thus locking them together. The edges *d*, *d* are double seamed together to prevent wind from lifting or rattling the cresting. When the ornamentation projects more than 9 inches, it is advisable to nail suitable lookouts on the top of the ridge pole.

The joints in crestings should be made in a manner similar to that already prescribed for cornices.

FINIALS.

73. Finials which are less than about 7 feet in height are usually built in the shop to conform with the drawings of the architect, and are taken to the building and erected in one piece. Larger finials, however, are usually set up in two or more pieces, according to their height, weight, and form. All the joints should be double seamed and soldered inside, in the same manner as cornice joints.

Finials having round members are built up from *spun* or *pressed* metal. Spun metal is preferable. Other forms are built together in different ways according to the shape of the members.

All finials must be securely supported to prevent them from sagging, and braced to prevent them from leaning out of plumb. The system of supporting and bracing required will depend upon the shape and size of the finial. In some finials a straight iron pipe alone will form a satisfactory support, while others must be provided with lookouts, like cornices, and often with braced framework. Fig. 58 shows a simple and efficient method of supporting a long, narrow finial on the peak of a conical roof. This finial is taken to the building in two pieces, and is joined together in position, with a lock seam around the ball. A 2-inch or 3-inch galvanized-iron pipe *b* is securely supported and braced to the framework of the roof. Horizontal partitions *c*, *c* are soldered to the inner surface of the finial and snugly fit the

iron pipe. These form braces and keep the finial straight. A few vertical gussets are soldered inside the ball to strengthen it vertically. A threaded pipe coupling is soldered inside the top ball so that this ball may be securely attached to the top of the pipe *d*.

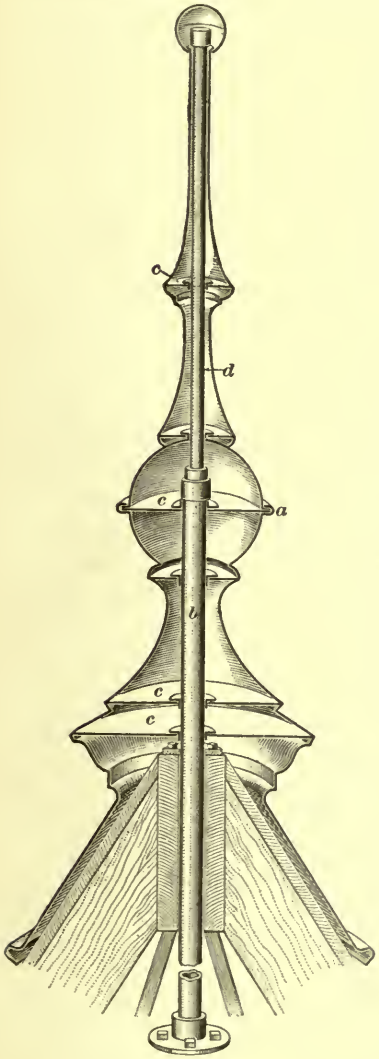


FIG. 58.

74. Weather vanes are a class of finials provided with a movable part which rotates on a vertical axis by the force of the wind. They are employed to show the direction in which the wind blows and consequently are provided with the letters N, S, E, W, located respectively north, south, east, and west of the axis of the finial. These letters are secured to the stationary part of the finial. An arrow, or some other form of indicator or pointer, is also employed in the construction; this is attached to the movable part of the finial. Fig. 59 is a vertical section through a simple weather vane. It is similar to the finial shown in Fig. 58 except that the top part is made to rotate. An iron pipe *a*, which rests on a solid footing, passes vertically through the apex of the roof. A collar at *b* and a cross-beam at *c* rigidly secure the pipe and keep it plumb. A special fitting called a double

cross receives the arms which support the four letters already mentioned. These arms also reinforce the ball. The top of the stationary sheet-metal work is riveted to a brass ring *e*.

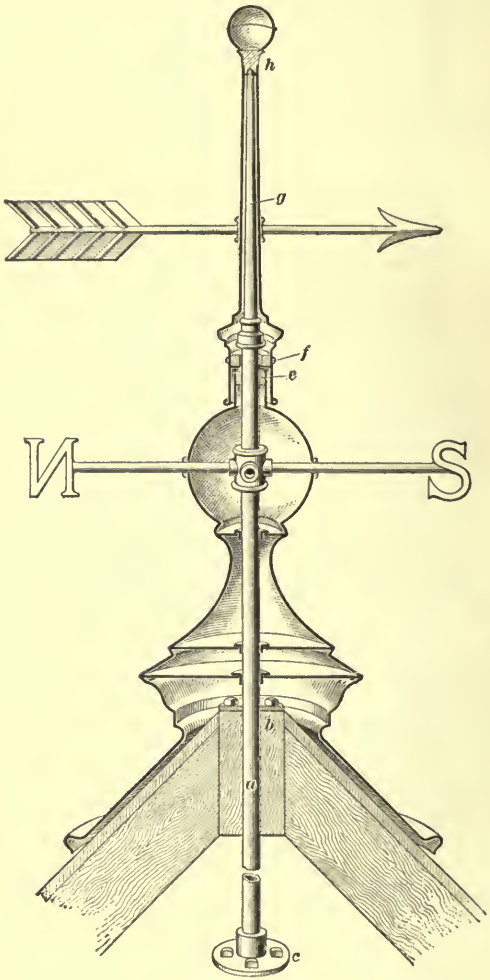


FIG. 59.

The bottom of the movable part of the vane is bolted to a brass ring *f*. These rings keep the copper in proper shape at the slip joint. The lower end of a tapered steel bar *g* is

screwed into the reducing socket on top of the pipe. The top end of the rod is tapered off to a sharp pivot point, and works in a brass socket *h*. This rod must be free and clear from the copper shell around it, so that the arrow may swing around to face the wind with the least possible resistance. The movable section must be carefully balanced; it should be so sensitive that a man can move it with his breath. The ring *f* is located under the reducing socket, and prevents the movable section from being thrown off in a storm.

INTERIOR SHEET-METAL WORK.

75. Sheet metal is seldom used in the interior of buildings except for covering walls, ceilings, etc., and even then it is only used for a cheap grade of work, so as to obtain an elaboration of ornamentation at a very low cost. The principal items for consideration are the methods of securing the sheets to the building and the selection of a design from manufacturers' stock.

It is customary for the sheet-metal worker to nail furring strips on the ceiling and walls at such distances apart as will conform with the design stamped on the sheets, but in no case should they be more than 1 foot apart. In selecting the furring strips for ceilings, particular care should be taken to allow for sufficient depth for any electric-wire conduits or gas pipes. The sheets are laid on the walls to overlap one another, and the nails are driven through the ornamentation in such a manner as to apparently form a part of the decoration. The lap seams should all be laid so that the light from the windows will shine against the edges of the sheets and thus avoid shadows which would indicate the location of the seams.

All sheet-metal wainscoting, baseboards, dados and chair rails, and, in fact, all ornamental sheet-metal work which is likely to be damaged by rough treatment, should be "pugged" behind with Portland cement.

All heavy moldings and cornices must be backed by

lookout brackets which are cut to the proper profile. All wood backing should be covered with asbestos sheets when it is desired to form a fireproof enclosure. Plain black-steel sheets should be dipped in iron oxide and linseed oil before they are put up. In all damp places it is advisable to use bright tin or zinc; the latter is preferable.

MATERIALS USED IN SHEET-METAL WORK.

76. Black Iron or Steel.—This form of iron or steel is used only for the very cheapest roofing and siding, also for interior decoration or fireproofing. No. 26 gauge is generally used. In all cases the sheets must be protected against corrosion by metallic paint or other suitable coatings.

77. Galvanized iron is used for sheet-metal siding, cornices, plain brackets, plain trusses, plain modillions, corrugated roofing, etc. No. 26 gauge metal is generally used throughout. No. 24 metal, however, is preferable for all large moldings.

78. Zinc is seldom used for covering buildings in the United States. But owing to the fact that it can be pressed into ornaments better than iron, it is employed for ornamental trusses, brackets, modillions, rosettes, festoons, etc., in galvanized sheet-metal fronts, and for balusters in balustrades. All zinc and galvanized sheet-metal work may be soldered on the face. All galvanized ironwork should be painted with a zinc body paint.

79. Cold-rolled copper is always used for copper cornices, moldings, columns, and all plain surface work which is to be formed in copper. The weight of the copper should not be less than 14 ounces, and it need not be more than 20 ounces on the very best class of buildings; 16-ounce copper is commonly used on good work, while 18-ounce is reserved for heavy moldings. All cold-rolled copper work

should be secured in place with brass or copper nails, screws, or bolts, as the conditions may require. All soldering should be concealed. When it is desired to paint copper work, the metal should be tinned all over the face, to prevent the copper from coming in contact with the paint.

80. Soft-Rolled Copper.—This copper is often called hot-rolled copper and is used for lining gutters, valleys, etc., and for pressed or hammered ornaments. The weight generally specified is 16 ounces, and 18 or 20 ounces on such work as may be subject to much wear and tear, either by expansion and contraction or by rough usage.

Soft copper, tinned on both sides, is best adapted for gutters and all other work which depends upon solder for tightness and strength. Copper cleats should always be cold rolled.

81. All sheet-metal seams should be soldered very slowly, because it takes time to properly sweat a seam; and very hot, well tinned soldering irons should be used.

Any mechanic discovered "rushing" a seam or hastily skinning it over with solder should be immediately discharged and all his work should be resweated by a careful man, as the durability of sheet-metal work depends chiefly upon the soldered seams.

Resin should be used as a flux for all tinned copper, and chloride of zinc for all plain copper, galvanized iron, and zinc. Raw muriatic acid or sal ammoniac should not be used as a flux.

82. Tarred Roofing Felt.—This form of building paper should be laid under all sheet-metal roof work and gutters to protect the under side of the metal from moisture and deleterious vapors, also to form a soft, protecting cushion for the metal.

83. All woodwork under sheet-metal roofing should be smooth and evenly laid and properly graded by the carpenter. Nail heads, knot holes, and sharp corners are detrimental to sheet-metal work.

ELECTRIC-LIGHT WIRING AND BELLWORK.

ELECTRIC-LIGHT WIRING.

FUNDAMENTAL PRINCIPLES.

ELECTRIC CIRCUITS.

1. An electric current may be produced commercially by means of either a primary battery or a dynamo-electric machine. The elementary form of battery is simply a vessel *A*, Fig. 1, containing alkaline or acidulated water, into which dip two plates, one of which *C* may be copper, and the other *Z*, zinc. If two wires be secured to these plates and their ends brought together, a current will flow through them from the copper to the zinc, and will be interrupted when they are separated. The copper is then said to be the **positive element,** and the zinc, the **negative element,** while the liquid is called the **electrolyte.** The path of the current from one plate through the liquid to the other plate, and through the wire to the starting point, is called the **electrical circuit.**

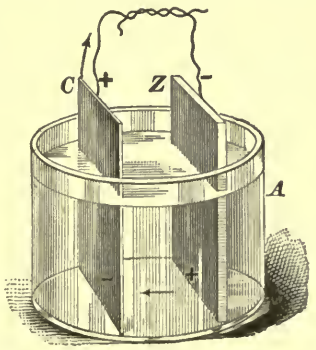


FIG. 1.

2. A circuit is **broken,** or **opened,** when its conducting elements are disconnected in such a manner as to prevent the current from flowing.

A circuit is **closed,** or **completed,** when its conducting elements are so connected as to allow the current to flow.

A circuit in which the earth, or ground, forms part of the conducting path is called an **earth,** or a **grounded,** circuit.

The **external** circuit is that part of a circuit which is outside or external to the electric source.

The **internal** circuit is that part of a circuit which is included within the electric source.

In the case of the simple voltaic cell mentioned in Art. **1,** the *internal circuit* consists of the two metallic plates, or elements, and the electrolyte; an *external circuit* would be a wire or any conductor connecting the free ends of the electrodes.

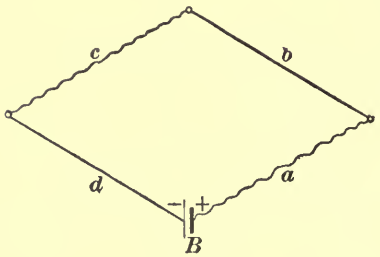


FIG. 2.

3. Conductors are said to be connected in **series** when they are so joined together as to allow the current to pass consecutively through each. For example, Fig. 2 represents a *closed* circuit, consisting of a simple voltaic cell *B*, and four conductors *a*, *b*, *c*, and *d* connected in *series*.

A circuit which is divided into two or more branches, each branch transmitting part of the main current, is a **derived,** or **shunt, circuit,** and the separate branches are said to be connected in **parallel,** or **multiple arc.** An example of a *derived* circuit, of two branches in *parallel*, is shown in Fig. 3. The main current flows first through the conductor *a*, then divides between the

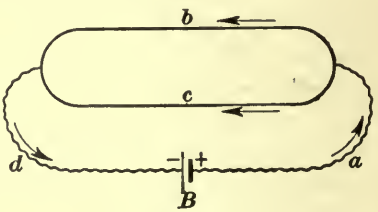


FIG. 3.

branches c and b, and finally unites, completing the circuit through the conductor d; the two branches c and b are the conductors which are connected in *parallel*, or *multiple arc*.

4. In every circuit containing a battery, there is at all times a tendency for a current to flow, even when the circuit is open, which is caused by the fact that there is always an electrical pressure acting. It is as though we had a tank full of water, and a stop-cock at the bottom communicating with a pipe. The pipe represents the wire of a circuit. There is always a pressure on the stop-cock, and as soon as we open it, a current of water flows through the pipe. The *amount* of water which would run out in a given time, say 1 minute, would depend on the size of the pipe; if it were of large cross-sectional area, more water would flow than if it were small, because the larger pipe offers less resistance. Another condition would also influence the rate of flow, namely, the height of water. If the tank were very high above the outlet, the pressure would be great. The flow, then, of water depends on the resistance offered, and on the pressure applied; the less the resistance or the greater the pressure, the more water will be forced through. The same holds good with respect to electricity. If the resistance of the circuit is low and the pressure high, a large current will flow; if the resistance is great, less current will pass, unless the pressure be raised to such a point as to overcome the increased resistance. This is the explanation of the fundamental law in electrical calculations, known as *Ohm's law*.

5. Ohm's Law.—*The strength of an electric current in any circuit is directly proportional to the electromotive force developed in that circuit and inversely proportional to the resistance of the circuit; i. e., is equal to the quotient obtained by dividing the electromotive force by the resistance.*

Ohm's law may be expressed thus:

$$\textit{Strength of current} = \frac{\textit{electromotive force}}{\textit{resistance}}. \qquad (1.)$$

6. The three principal units used in practical measurements of a current of electricity are:

(*a*) *The* **ampere,** *or the practical unit denoting the rate of flow of an electric current, or the strength of an electric current.*

(*b*) *The* **ohm,** *or the practical unit of resistance.*

(*c*) *The* **volt,** *or the practical unit of electrical potential or pressure.*

The usual form in which Ohm's law is given is

$$C = \frac{E}{R}. \qquad (2.)$$

The electromotive force, or pressure, (E) is here expressed in *volts*, the resistance (R) in *ohms*, and the current (C) in *amperes.*

THE AMPERE.

7. The strength of an electric current can be described as a *quantity* of electricity flowing continuously every second; or, in other words, it is the rate of flow of electricity just as the current expressed in *gallons per minute* is the *rate of flow* of liquids. When one unit quantity of electricity is flowing continuously every second, then the rate of flow, or the strength of current, is *one ampere;* if two unit quantities are flowing continuously every second, then the strength of current is *two amperes*, and so on. It makes no difference in the number of amperes whether the current flows for a long period or for only a fraction of a second; if the quantity of electricity that would flow in one second is the same in both cases, then the strength of the current in *amperes* is the same.

THE OHM.

8. The unit of electrical resistance, now universally adopted, is called the **international ohm.** One international ohm is the resistance offered by a column of pure mercury 106.3 centimeters in length and 1 square millimeter in sectional area at 32° F., or the temperature of melting ice. The dimensions of the column expressed in inches are as follows: length 41.85 inches, sectional area .00155 square

inch. Hereafter, the word "international" will be omitted, and simply the word "ohm" used; the *international ohm*, however, as defined above, will always be implied unless otherwise stated.

9. In Table 1 are given various data respecting the copper wire used in electrical installations. In the first column is the gauge number by American Wire Gauge; in the second column is the diameter as measured in *mils* (one mil = one one-thousandth of an inch); the third column shows the area of cross-section in circular mils. It is usual to adopt this method for a round wire, instead of the old way of expressing the area in fractions of a square inch, in which case the diameter is squared and the product multiplied by .7854, as explained in *Geometry and Mensuration*. If the second operation be omitted, and the diameter, as measured in thousandths of an inch, be only squared (or multiplied by itself), the result is expressed in circular thousandths, or circular mils.

EXAMPLE.—What is the area in circular mils of a wire $2\frac{1}{2}$ inches in diameter?

SOLUTION.— $2\frac{1}{2}$ in. = 2,500 mils. $2{,}500^2 = 2{,}500 \times 2{,}500 = 6{,}250{,}000$ circular mils. Ans.

The resistance of copper wire being low, a unit length of 1,000 feet is usually taken in tables of resistance, and this unit is considered in the eighth column.

10. The resistance of a given conductor increases as the length of the conductor increases; that is, the resistance is directly proportional to the length of the conductor. For example, if the length of a conductor be doubled, its resistance will be doubled.

The resistance of any length of conductor may be found by the following formula:

$$R = \frac{L R_1}{1{,}000}, \qquad \textbf{(3.)}$$

where R = required resistance;
L = length of conductor;
R_1 = resistance per 1,000 feet of conductor.

TABLE 1.

AMERICAN, OR B. & S., GAUGE.

Gauge No.	Diameter Mils (d). 1 Mil = .001 In.	Area.		Weight and Length.			Resistance. Ohms per 1,000 Feet.	Current Allowed. Amperes	Gauge No.
		Circular Mils (d^2).	Square Inches ($d^2 \times .7854$).	Pounds per 1,000 Feet.	Pounds per Mile.	Feet per Pound.			
0000	460.000	211,600.00	.1661900	639.33	3,375.700	1.56	.051	175	0000
000	409.640	167,805.00	.1317900	507.01	2,677.000	1.97	.064	145	000
00	364.800	133,079.00	.1045200	402.09	2,123.000	2.49	.081	120	00
0	324.950	105,592.00	.0829320	319.04	1,684.500	3.13	.102	100	0
1	289.300	83,694.00	.0657330	252.88	1,335.200	3.95	.129	95	1
2	257.630	66,373.00	.0521300	200.54	1,058.800	4.99	.163	70	2
3	229.420	52,634.00	.0413390	159.03	839.680	6.29	.205	60	3
4	204.310	41,742.00	.0327840	126.12	665.910	7.93	.259	50	4
5	181.940	33,102.00	.0259980	100.01	528.050	10.00	.326	45	5
6	162.020	26,250.00	.0206170	79.32	418.810	12.61	.411	35	6
7	144.280	20,817.00	.0163490	62.90	332.110	15.90	.519	30	7
8	128.490	16,509.00	.0129660	49.88	263.370	20.05	.652	25	8
9	114.430	13,094.00	.0102840	39.56	208.880	25.28	.824		9
10	101.890	10,381.00	.0081532	31.37	165.630	31.88	1.040	20	10
11	90.742	8,234.10	.0064670	24.88	137.370	40.20	1.311		11
12	80.808	6,529.90	.0051286	19.73	104.180	50.69	1.653	15	12
13	71.961	5,178.40	.0040671	15.65	82.632	63.91	2.084		13
14	64.084	4,106.80	.0032254	12.41	65.525	80.59	2.628	10	14

Rule.—*To find the resistance of any length of wire, divide that length in feet by 1,000, and multiply by the figure giving the resistance of that wire per thousand feet, as found in Table 1.*

EXAMPLE.—What is the resistance of a No. 4 wire, 1,530 feet in length?

SOLUTION.—The resistance R_1 per 1,000 feet of No. 4 wire is, from the table, .259 ohm. The length L is 1,530 feet. Then, by formula 3,

$$R = \frac{1{,}530}{1{,}000} \times .259 = .396 \text{ ohm.} \quad \text{Ans.}$$

11. The resistance of a given conductor diminishes as its sectional area increases; that is, the resistance varies inversely as the sectional area of a conductor. For example, if the sectional area of a conductor be doubled, its resistance will be halved.

EXAMPLE.—No. 8 wire has a resistance of .652 ohm per 1,000 feet. What will be the resistance of 1,000 feet of a wire having three times the sectional area of No. 8 wire?

SOLUTION.—A wire three times the area of No. 8 will have one-third its resistance, or $\frac{.652}{3} = .217$ ohm. Ans.

The resistance of two or more conductors connected in *series* (Art. **3**) is equal to the sum of their separate resistances. For example, if four conductors, having separate resistances of 8, 12, 22, and 34 ohms, respectively, are connected in series, their total or joint resistance would be $8 + 12 + 22 + 34 = 76$ ohms.

12. The **microhm** is a unit of resistance devised to facilitate calculations and measurements of exceedingly small resistances, and is equal to *one millionth* ($\frac{1}{1\,000\,000}$) of an ohm. Hence, to express the resistance in *microhms*, multiply the resistance in ohms by 1,000,000; and, conversely, to express the resistance in ohms, divide the resistance in microhms by 1,000,000. For example, .75 ohm $= .75 \times 1{,}000{,}000 = 750{,}000$ microhms; or, 750,000 microhms $= 750{,}000 \div 1{,}000{,}000 = .75$ ohm.

The **megohm** is a unit of resistance intended for the

measurement of very high resistances, such as the insulation of cables, and is equal to one million (1,000,000) ohms. Hence, to express the resistance in megohms, divide the resistance in *ohms* by 1,000,000; on the other hand, when the resistance in megohms is given, multiply by 1,000,000 in order to express the same in ohms. For example, 12,500,000 ohms = 12,500,000 ÷ 1,000,000 = 12.5 megohms; or 12.5 megohms = 12.5 × 1,000,000 = 12,500,000 ohms.

THE VOLT.

13. In mechanics, pressures of all kinds are measured by the *effects* they produce; similarly, in electrotechnics, *potential* is measured by the effect it produces, and the *volt*, or *practical unit of potential*, is that electromotive force which will maintain a current of *one ampere* in a circuit whose resistance is *one ohm*. With a known resistance in ohms and a known strength of current in amperes, the electromotive force in volts is determined by Ohm's law, for, by transposing, $C = \frac{E}{R}$ may be written $E = CR$.

DROP OR LOSS OF POTENTIAL.

14. Referring again to water flowing in a pipe, though the *quantity* of water which passes is the same at any cross-section of the pipe, the *pressure per square inch* is not the same. Even in the case of a horizontal pipe of the same diameter throughout, the water when flowing suffers a *loss* of head or pressure. It is this difference of pressure that causes the water to flow between two points against the friction of the pipe.

This is precisely similar to a current of electricity flowing through a conductor. Though the *quantity* of electricity that flows is equal at all cross-sections, the *electromotive force* is by no means the same at all points along the conductor. It suffers a loss or drop of electrical potential in

the direction in which the current is flowing, and it is this difference of electrical potential that causes the electricity to flow against the resistance of the conductor. Ohm's law not only gives the strength of the current in a closed circuit, but also the *difference of potential* in volts along that circuit. The difference of potential (e) in volts between any two points along a circuit is equal to the product of the strength of the current (C) in amperes and the resistance (R) in ohms of that part of the circuit between those two points, or $e = CR$; e also represents the *loss* or *drop* of potential in volts between the two points. If any two of these quantities are known, the third can be readily found; for, by transposing,

$$C = \frac{e}{R} \text{ and } R = \frac{e}{C}.$$

EXAMPLE.—Fig. 4 represents part of a circuit in which a current of 3 amperes is flowing. The resistance from a to b is 1.5 ohms; from b to c is 2.3 ohms; and from c to d is 3.6 ohms. Find the difference of potential between a and b, b and c, c and d, and between a and d.

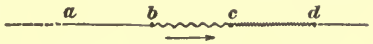


FIG. 4.

SOLUTION.—We apply the formula $e = CR$ derived from Ohm's law.

The difference of potential between a and $b = 3 \times 1.5 = 4.5$ volts.

The difference of potential between b and $c = 3 \times 2.3 = 6.9$ volts.

The difference of potential between c and $d = 3 \times 3.6 = 10.8$ volts.

The difference of potential between a and $d = 4.5 + 6.9 + 10.8 = 22.2$ volts; or, in other words, the *loss* or *drop* of potential caused by a current of 3 amperes flowing between a and d is 22.2 volts.

15. In a great many cases, it is desirable to have the current flow from the source a long distance to feed lamps or motors, and return without causing an excessive drop or loss of potential in the conductors leading to and from the two places. In such circuits, the greater part of the total generated electromotive force is expended in those lamps or motors, and only a small fraction of it is lost in the rest of the circuit. Under these conditions, it is customary to decide upon a certain *drop* or *loss of potential* beforehand; and from that and the current, calculate the resistance of the two

conductors. For this purpose the formula $R = \frac{e}{C}$ (Art. **14**) may be used.

EXAMPLE.—It is desired to transmit a current of 5 amperes to a motor situated 500 feet from the source; the total generated E. M. F. is 120 volts, and only $\frac{1}{10}$ of this potential is to be lost in the conductors leading to and from the motor. (*a*) Find the resistance of the two conductors, and (*b*) the resistance per foot of the conductors, assuming each to be 500 feet long.

SOLUTION.—(*a*) $\frac{1}{10}$ of 120 volts = 12 volts, which represent the *drop* or *loss* of potential on the two conductors. Let e = 12 volts; C = 5 amperes; and R = the total resistance of the two conductors. Then,

$$R = \frac{e}{C} = \frac{12}{5} = 2.4 \text{ ohms.} \quad \text{Ans.}$$

(*b*) The resistance per foot of any conductor is found by dividing the total resistance of a conductor by its length in feet; hence, since 2.4 ohms is the resistance of two conductors, each 500 feet long, then the resistance per foot of the conductors $= \frac{2.4}{2 \times 500} = .0024$ ohm. Ans.

WIRING FOR INCANDESCENT LIGHTS.

16. In Art. **1** reference was made to two methods of current generation, namely, by means of batteries and by dynamo-electric machinery. For electric lighting, the only practical method is the latter. Current is generated by revolving coils of insulated wire, mounted on an iron core and suitably connected together, in front of powerful electromagnets. The power for this purpose is supplied by a steam engine, or in some cases by turbines, when steady water-power is available. The current is led to the place of utilization, or the distributing center, by means of heavy copper cables covered with some insulating substance, such as gutta percha or rubber, to prevent electrical contact with the supports or other bodies which they may approach. These two materials are most commonly employed for the insulating covering of electric wires, being flexible and waterproof. Other insulators are paper, oils, porcelain, wood, silk, cotton, shellac, ebonite or hard rubber, paraffin, mica, glass, and dry air.

CONDUCTORS.

17. Conducting cables or wires for any system of electric house lighting are always arranged as a closed circuit; that is, one wire must be provided to convey the current to the lamps, and another one to allow it to flow back to the starting point. It is not, however, necessary to provide one set of wires for each lamp for the entire distance. The arrangement should be somewhat like the trunk and branches of a tree. Heavy wires carry the whole current for the house up to the first distributing point, and wires continually branch out, becoming smaller at each such division. The name *lead* (pronounced *leed*) is frequently given to the conductors in a house.

18. Electric-light conductors for inside wiring are of two kinds: solid and stranded. The heavy conductors, which carry the whole current to a distributing center, are called **feeders,** and are usually made of stranded wire for the sake of flexibility; that is, they are composed of a large number of interwoven wires of small diameter. Fig. 5 shows the construction of such a cable. The wires w project at the end, the insulation being all removed; a thin sheet of rubber r is first laid over, then a gutta-percha compound g, and over this a covering of braid b as a mechanical protection. For smaller conductors, such as mains or submains, a solid wire may be used for the core, the insulation

FIG. 5.

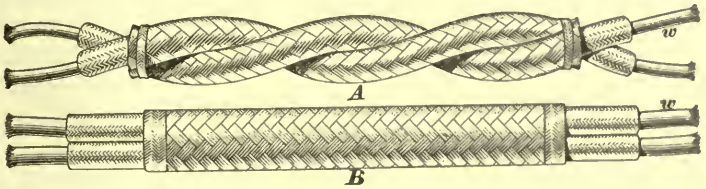


FIG. 6.

being of the same description. For connection to single lamps, a double flexible conductor is used, such as A or B, Fig. 6. The core of each is formed of many fine wires w, insulated

with rubber and braided. These two sets of conductors are then twisted together, and may be used to suspend the lamp, or they may be laid side by side and braided together.

19. When it is necessary to make joints between wires, it is important to remember that the work cannot be too well done. Under no circumstances should a joint be left unsoldered. When connecting a branch line to the main, the insulation is cut away as shown in Fig. 7; the cut should not be made straight down towards the wire with the edge of the knife, forming a sharp shoulder on the insulation, as the knife is very likely to make a nick in the wire, and subsequent bending might produce a crack at this point. Such a fault would increase the resistance locally, and cause heating, and, possibly, fire risk. In the illustration, the branch wire *b*, after being carefully bared of insulation and scraped clean with sandpaper, is shown wrapped over the main *m*, similarly exposed. This operation should be done with a pair of pliers of convenient size, and the turns of *b* should be close together. The joint should then be soldered, no acid being used, but resin only, as a flux, the reason being that it is impossible to clean off all the acid after the joint is finished, as some remains in the crevices and will eventually corrode the wire and break the electrical circuit. When the joint is cool, the wire is held firmly by the solder; all the exposed wire should then be covered by wrapping rubber insulating tape carefully over it, continuing across a short distance on the main insulation. When, however, the outer covering is braided, this should never extend into the insulation of the joint; as, when exposed to dampness, the moisture is likely to penetrate and cause trouble. It may here be remarked that it is not so easy to make a resin joint as one on which acid is used, which explains the disfavor in which the former is usually held by poor workers. Acid removes grease from

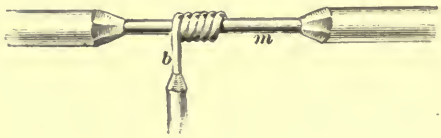


FIG. 7.

the wire, such as a careless workman may have smeared on from his fingers, but when the wire is not handled after

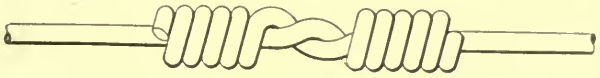


FIG. 8.

cleaning, resin will make a good joint. An alternative method is to tin both wires before wrapping, using acid as a flux; then wipe carefully, cleaning thoroughly, to remove all trace of acid, and wrap over, using pliers to bend the wire. The joint should then be completed, with resin as a flux. When two wires are to be connected together to form a continuous conductor, the Western Union joint, Fig. 8, is employed, the wires being twisted one over the other, soldered and taped.

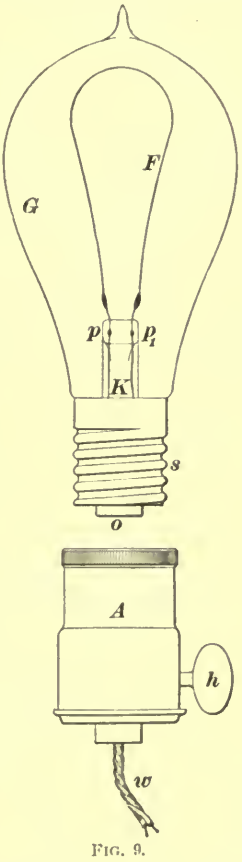


FIG. 9.

HOUSE FIXTURES.

20. The **incandescent lamp**, Fig. 9, is provided with a composite base, made to fit in a corresponding socket connected with the house wiring. The filament *F* is made of a thread of carbon, which material has a very high resistance. When the filament is enclosed in a vessel from which the air has been removed, and a current is passed through it, it becomes incandescent and gives out light. Connections are made from one end of the filament to the outside metallic screw sheathing *s*, and from the other end to the brass plug *o* at the bottom. The socket, Fig. 10, has a screw shell *s* inside, large enough to receive the base of the lamp, and at

its center an insulated tongue *t*, which presses against the plug on the lamp when the latter is screwed in. The wires supplying current are connected, one to the tongue *t* by means of the screw *a* at its lower end, the other to a similar screw (not shown) on the lower contact strip *c*. When the key *k* is turned into the vertical position, as drawn, the bridge *b* completes the circuit between

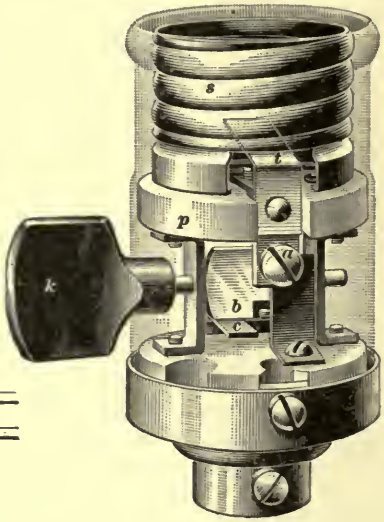


FIG. 10.

the strip *c* and the sheathing *s*, pressing against a contact piece on the lower side of the porcelain plate *p*, which is in electrical connection with *s*. When the key is turned through 90°, the contact between *c* and *s* is broken, and the light is extinguished. The socket may be suspended from a flexible cord (*A*, Fig. 6) attached to a ceiling rosette, or fixed to a bracket or electrolier.

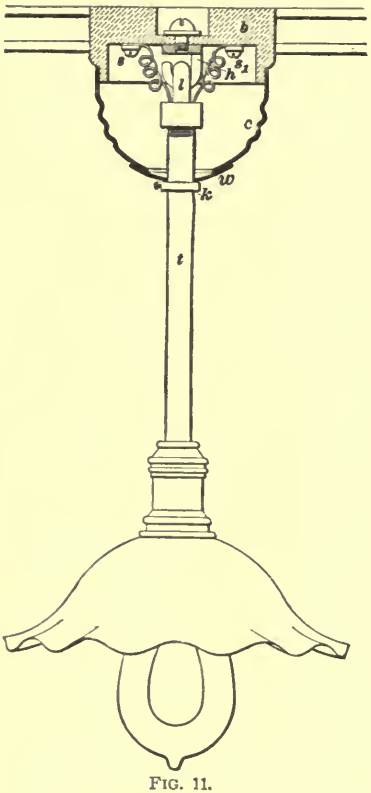


FIG. 11.

21. A **rosette pendant** is shown in Fig. 11. The leads are brought to the screws *s*, s_1 on the insulating

base *b*, and the fixture wires are also secured to the same contact-blocks, and pass down inside the tube *t* to the lamp. A casing *c* fits up against the base, the opening at the lower end being larger than the tube, and closed by a washer *w* held by a collar *k*. The pendant is thus free to swing a certain amount, being supported on a hook *h* passing through a loop *l* on the tube. When flexible-cord suspension is used, a knot should be made in the cord inside the rosette, and also, if practicable, in the lamp socket, to prevent the weight coming on the connections.

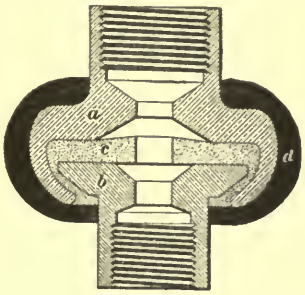


FIG. 12.

22. Combination fixtures for gas and electric light are frequently installed. The fixtures must in this case be insulated from the gas piping of the building, a joint being used, such as is shown in Fig. 12, in which the two metallic unions *a* and *b* are separated from each other by an insulating cement *c*, and the whole joint further protected by a covering *d* of hard rubber or similar material. No soft rubber must be used in the construction. At the point where the wires approach

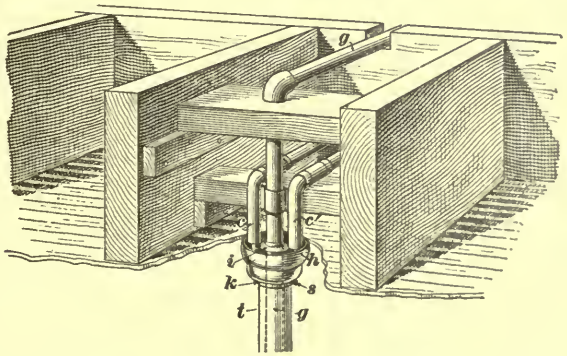


FIG. 13.

the fixture, they must be kept clear of the grounded gas pipe, and the outer shell at the point of entrance

must be large enough to allow this. In Fig. 13 the arrangement of wires is shown with relation to the piping for a chandelier. The gas pipe *g* is carried across between the floorbeams, and the insulating joint *i* is placed as already indicated, to form the connection. The wires are brought over in independent insulating conduits *c*, *c'*, as described in detail later, and inserted through the tube *t* surrounding the gas pipe *g*. There must be between these at least a quarter of an inch clear space, to conform with the insurance regulations. After the wires are in place, the hood *h* is pushed up against the ceiling, and secured by means of the collar *k* furnished with a setscrew *s*. It is necessary to examine carefully all edges of the metal shell, that any rough parts near the wires be smoothed down. The hood when in position must clear the wire, and not press it against the insulating joint; and, to guard against the entrance of moisture, the upper end of the fixture should be sealed.

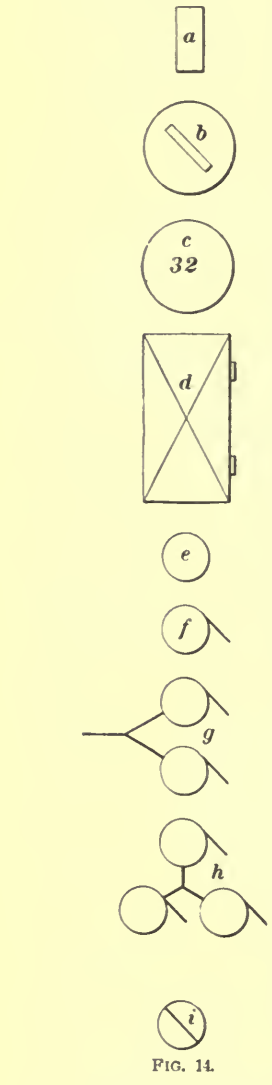


FIG. 14.

23. Conventional Symbols.—In the diagrams of lighting circuits in the following pages, the symbols given below will be used. See Fig. 14.

Symbol *a* is a safety plug, or cut-out.

Symbol *b* is a wall switch.

Symbol *c* is a 32-candlepower lamp.

Symbol *d* is a dynamo.

Symbol *e* is a 16-candlepower lamp.

Symbol *f* is a 16-candlepower lamp with a key socket.

Symbol *g* is a 2-arm bracket with key sockets.

Symbol *h* is a 3-light chandelier with key sockets.

Symbol *i* is a 10-candlepower lamp.

SAFETY CUT-OUTS.

24. Safety cut-outs are devices that break a circuit before a wire becomes sufficiently heated by the passage of a current to cause danger of fire. They are also used to protect lamps. Fig. 15 shows an incandescent cut-out for

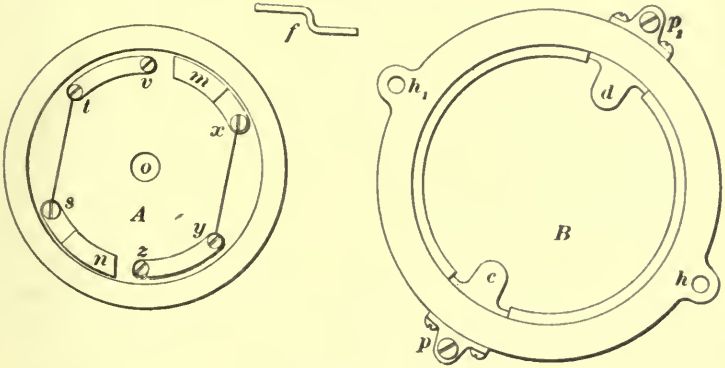


FIG. 15.

small currents. It is called a rosette cut-out, and is principally used on ceilings where a lamp drops from the supply wires. The figure shows the inside view of the two halves. They are both composed of porcelain, upon which metallic connection pieces are screwed. The half *B* is screwed to the ceiling through the holes *h* and h_1. The ceiling or supply wires are respectively connected to the binding posts *p* and p_1, which are themselves connected to the two projecting elastic plates of metal *c* and *d*.

The half *A* has two projecting metallic pieces *m* and *n*, which hook in under *c* and *d*, and make the connections when the two halves are put together. The side view of *m* or *n* is given at *f*. Upon each of these pieces at the end that rests against the porcelain is a binding screw *s* or *x*. Two small metallic plates, each carrying a pair of binding screws *t* and *v*, or *z* and *y* are screwed upon the porcelain at diametrically opposite points, and the lamp conductors, entering at hole *o*, are connected respectively to *v* and *z*. If flexible cord is used, it should be knotted as already

explained, Art. **21,** to sustain the weight of the lamp. Between the two binding screws *t* and *s*, as well as between *x* and *y*, are respectively connected two strips of a fusible alloy. This alloy melts and breaks the circuit when the current increases above a given value.

The current starts from one supply wire and flows through *d*, *m*, and the alloy or fuse wire *x y* to *z*. Then it flows through the lamp to *v*, through the fuse wire *t s* to *c*, and out to the other supply wire. The two halves are connected by a screwing motion which rubs the contact pieces together.

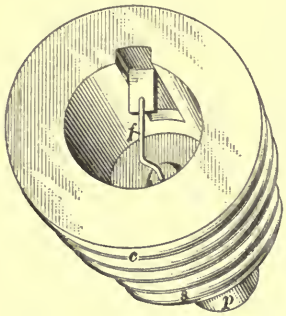


FIG. 16.

25. A convenient form of fuse is shown in Fig. 16, called a **plug cut-out,** which is intended to be screwed into a socket similar to that used for lamps, and may be employed on branch circuits which do not carry a heavy current. The screw sheathing *s* and plug end *p* are insulated from each other, except when joined by the fuse wire *f*, which is soldered between them. A brass cap is screwed on the larger end of the plug at *c* to protect the fuse.

26. The ordinary form of detachable fuse is shown in Fig. 17. The contact pieces *a* and *b* are made of sheet copper, and are intended to be clamped by screws to the cable tips or terminals at the distributing boxes or closets where the different circuits branch off. A strip *c* of fusible lead alloy is soldered to each contact piece, its cross-section being proportional to the maximum current to be carried, which is stamped on the copper ends.

FIG. 17.

27. A good form of connection between the mains and a branch circuit is illustrated in Fig. 18. This is known as a

branch block. The mains may be connected at m, m'; the wires pass under the projecting ledges l, l'; and the branch wires are secured at c, c'. The fuses are held between the screws a and b, c and d. To prevent damage when a fuse "blows," or melts, a porcelain cover is fitted over the face of the block.

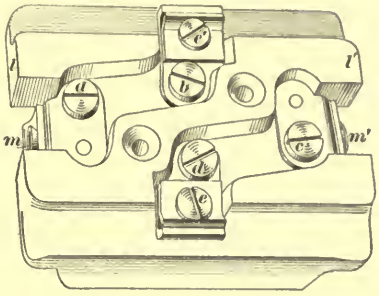


FIG. 18.

28. For the large currents of feeders or mains a double porcelain fuse block, as in Fig. 19, is used, the wires from the point of supply being inserted at one end, as at m, m, and the line continued from the terminals m', m', at the other end. The fuses are

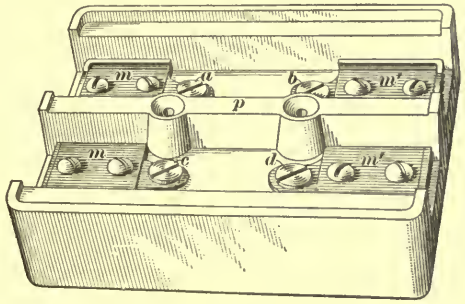


FIG. 19.

inserted between the screws a and b, and between c and d. The two sides of the circuit are separated by the partition p, so that all danger of short circuit is eliminated.

29. As a guide to the carrying capacity of fuses, the following table may be consulted, but it is to be pointed out that the fusing current depends upon the particular proportion of the metals used in the alloy, and their selection; also on the length of fuse and the character of the terminals.

Diameter. Mils.	B. & S. Gauge (Approximate).	Amperes.
.017	25	3
.020	24	4
.032	20	7
.042	18–17	10
.056	15	15
.065	14	18
.075	13–12	25
.085	12–11	28
.096	11–10	31
.111	9	36
.130	8	50
.150	7–6	70

SWITCHES.

30. A **switch** is an appliance interposed in an electric circuit for the purpose of readily, and without danger, opening or closing that circuit. For large currents some form of

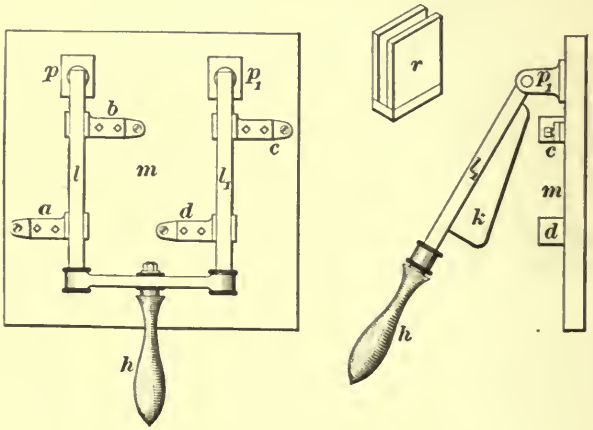


FIG. 20.

knife switch, such as that shown in Fig. 20, is employed. The two copper levers l and l_1 carry plates of copper in the

shape of knife blades, shown at *k* in the side view. These knife blades fit between elastic metallic plates shown in perspective at *r*. There are four pairs of these plates connected respectively to the metallic pieces *a*, *b*, *c*, and *d*, so that each knife blade connects with two pairs. The levers are pivoted at *p* and p_1, and are moved by the handle *h*.

The line wires are both cut, and the ends of one are connected respectively to *a* and *b*, while the ends of the other are connected to *c* and *d*. It will now be seen that when handle *h* is pushed down, the circuit is complete, but when it is pulled up, the circuit is broken in both wires. The base is of slate, and is shown at *m*.

31. Plug switches are frequently used for the connection between the house wiring and the street mains. This switch consists simply of a conical metal plug *p*, Fig. 21,

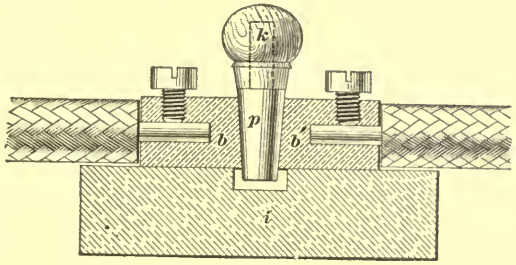


FIG. 21.

with a wooden knob *k* for a handle, and is pressed into contact with two blocks *b*, *b'*, forming part of the conductor circuit, and mounted on an insulating base *i* secured to the wall.

32. A form of double-pole switch for currents up to 50 amperes is shown in Fig. 22. The positive and negative leads are brought up to the hole in the base *b*, and connected one to each of the terminals shown, by means of the screws, *s*, *s'*. The leads for the lamps are connected in a similar manner to corresponding terminals on the other side of the switch, and the circuit is completed by

forcing the arm *a* into contact with these terminals, thereby bridging over the gap between them. The rubber knob *k* is fastened to a pin passing vertically through the frame *f* and secured to the springs *c*, *c'* at the lower end in such a way as to form a togglejoint. When the knob is drawn upwards, the springs are compressed, and, on passing the center, they suddenly force the contact arm downwards. In like manner, on pressing the knob down, contact is again broken.

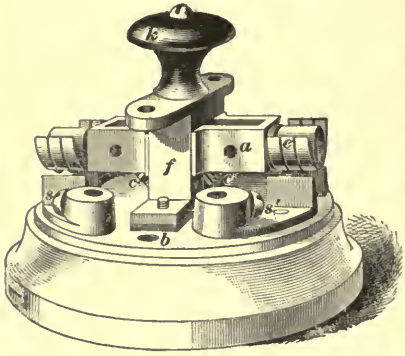


FIG. 22.

33. Fig. 23 shows a double-pole switch for small currents. It is usually fastened to the wall, the screws passing through the base. The cylinder *e*, made of china or other insulating substance, has brass contact plates *p* on opposite sides, against which press brass or copper springs when the cylinder is in the position indicated in the illustration. Four terminals are provided, lettered *a*, *b*, *c*, *d*, and the wires for connection to them are brought up through the holes in the base, one of which is visible. The incoming wires, positive and negative, are connected to the terminals *b* and *d*, and the outgoing wires

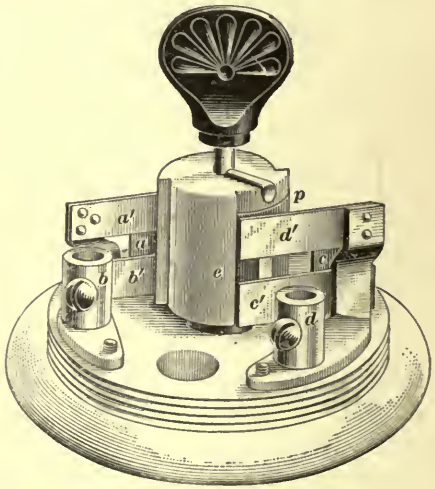


FIG. 23.

to *a* and *c*. The springs *a'*, *b'*, *c'*, *d'* are riveted to the terminals *a*, *b*, *c*, *d*, respectively, so that when the switch is turned to the position shown, the circuit is completed between terminals *a* and *b*, and between *c* and *d*. A quarter-turn breaks the contact, for the springs then rest only on the china cylinder. A screw cover is provided to enclose the body of the switch, the handle alone projecting.

34. A single-pole switch may only be used for a few lamps, as, for instance, an electrolier, or the lights in a small room. In Fig. 24 the lead is brought to the screw terminal marked *a*, and the wire from the lamps is secured to *b*, the return current passing through the other lead, which is connected directly to the main. When the key *k* is turned through 90°, the spring *s* is pressed against the tongue *t*, completing the circuit between *a* and *b*. Another quarter-turn releases the spring and extinguishes the lights. The wires are brought to the contacts through a hole *h* in the base, and a cover is fitted over, as in the case of the last mentioned switch.

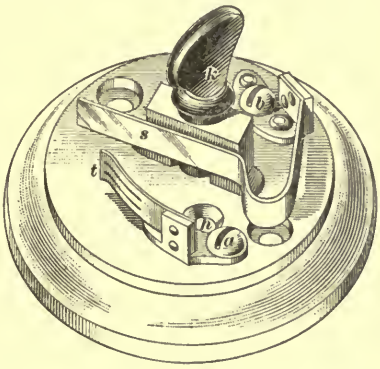


FIG. 24.

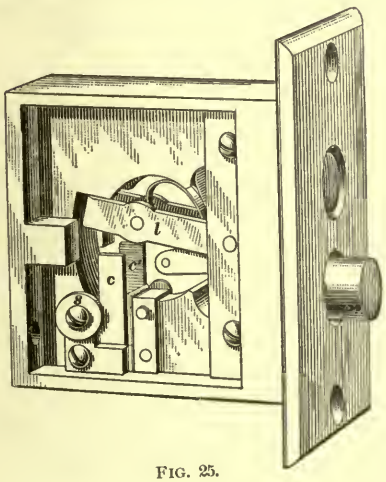


FIG. 25.

35. Flush switches are so called because they are intended to be let into the wall, hardly projecting beyond the surface. The

mechanism is usually of the same style as that in Fig. 23 or Fig. 24, but the cover is simply a plate, and the body of the switch is concealed. Another form is given in Fig. 25, called a *Flush Double Push Switch.* This is a single-pole switch, and is operated by pressing one or the other button, one being out when the other is in. The contact lever *l* is forced between the brass leaves *c*, *c'* by means of a spring and toggle-joint, somewhat as in Fig. 22. One wire is wound around the screw *s*, and is held under the washer, and the other wire is secured in a similar manner on the other side. These two ends of wire belong to the same lead, which is cut at the point where the switch is to be inserted. The interior of the switch is protected by plates which are fitted over the sides.

The external appearance of the usual form of flush switch is simply a nickeled brass plate on a wooden block let into the wall, a recess being provided in the plate for the key, which, therefore, projects only a slight distance from the level of the plate.

36. When connecting up switches, great care must be taken to enter the wires at the correct terminals, and the path of the current should be traced through, in order to be sure that the closing of the switch will not short circuit the system.

CONNECTIONS FOR INCANDESCENT LAMPS.

37. There are three methods in general use by which electric incandescent lamps are connected in circuit, namely, the *multiple-arc*, or *parallel*, system, the *multiple-series* system, and the *three-wire* system.

Multiple-Arc System.—Fig. 26 shows the multiple-arc system, where the negative conductor *a b* and the positive conductor *c f* supply current to the lamps from the constant-potential dynamo *d*. The lamps *l*, *l*, etc. are connected in parallel between the two conductors, and the amount of current to be furnished depends directly upon the number of

lamps used. Each lamp is entirely independent of all the others, and its extinction does not affect the brightness of the rest.

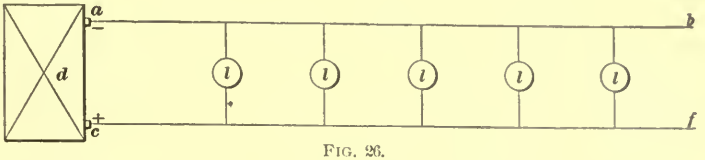


FIG. 26.

The lamps used in this system should all be of the same working voltage, and equal to that maintained between the two conductors. If the E. M. F. between these is 110 volts, only 110-volt lamps must be used.

38. Multiple-Series System.—Fig. 27 shows the multiple-series system. Two or more lamps are arranged in series groups, and these groups are connected in parallel

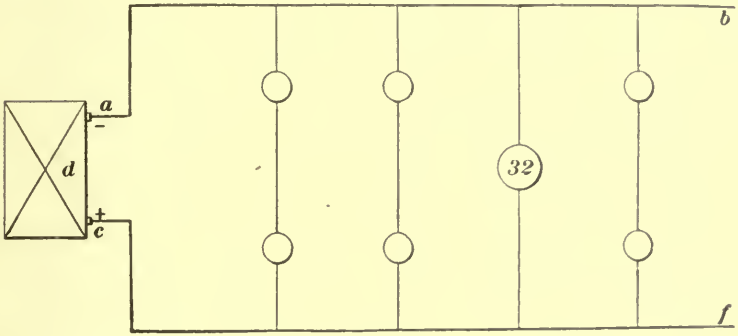


FIG. 27.

between the conductors *a b* and *c f*. Manifestly, when one lamp is burned out, all the other lamps in that group will also cease to glow. To obviate this difficulty, automatic devices which close the circuit across the lamps have been used, but have not given complete satisfaction. A diagram of one of these devices is shown in Fig. 28. The lamp is shown at *l*, an electromagnet in series with the lamp at *m*, and *a* is a lever carrying an armature which is attracted by

the electromagnet. When the current flows through the lamp, the electromagnet is energized, and the lever *a* is held up tightly against its stop *e*. When, however, the lamp is burned out or the filament is destroyed from any cause, the magnet releases its armature, which is pulled by a spring *s* against the contact *f*. The circuit is thus closed around *b*–*f*–*a*–*d*.

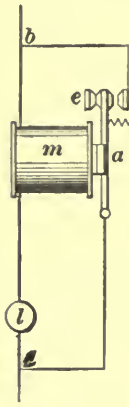


FIG. 28.

If there be 200 volts pressure between the conductors, one 200-volt lamp, two 100-volt, or four 50-volt lamps may be connected across.

This system, on account of its adaptability to lamps of different voltages and candlepowers, is occasionally used to light stores or large buildings.

39. Three-Wire System.—Fig. 29 shows the three-wire system. The two dynamos *d* and d_1 are connected in series, the positive lead of one being joined to the negative lead of the other. From the remaining terminals of the machines, the main leads *a b* and *c f* are brought out, and the third or neutral wire *e h* is connected to the short lead, already mentioned, which joins the two dynamos. The lamps are connected between this neutral conductor and either of the outer mains. It is, therefore, necessary that the E. M. F. of each dynamo should be the same, in order that lamps of one voltage may be used throughout. When, as in the figure, there is an equal number of lamps on each side of the system, it will be observed that no current will pass through the neutral wire. Considering the outer wires as the main conductors, this becomes a 200-volt system, if the lamps used are for 100 volts; for each of them, such as *l* and l_1, would require an E. M. F. of 100 volts at its terminals *m*, *n* and *n*, *o*, making a total E. M. F. between *m* and *o* of 200 volts. The advantage of such an increase in voltage will be pointed out later. It is not possible in practice to have the two sides of the system always perfectly balanced, and when the current required for one side is greater than

that used on the other side, the difference in amount will return by way of the third wire. This extra current changes in direction of flow, according as one side or the other has the larger number of lamps burning.

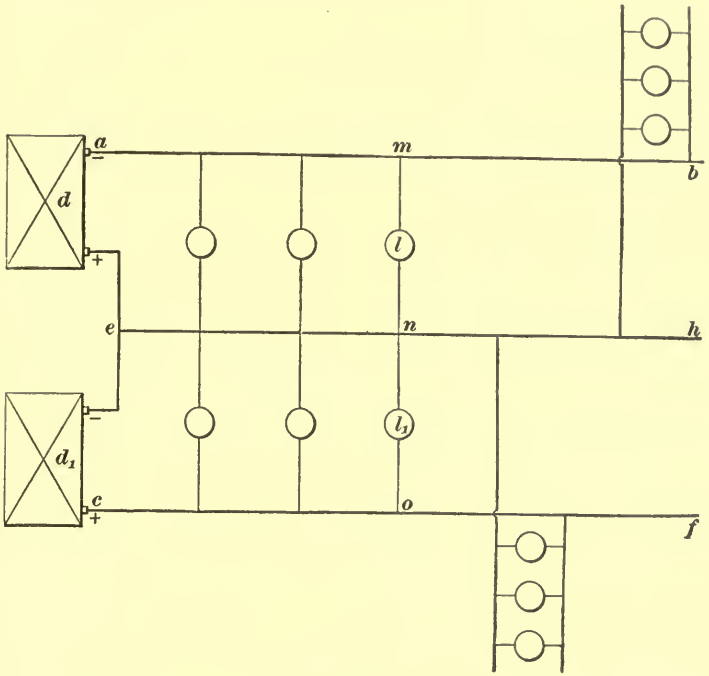


FIG. 29.

It will be seen that the three-wire system is quite like the multiple-series with groups of two lamps. There is, however, the important difference that when a lamp on the three-wire system burns out or is switched off, none of the remaining lamps are affected.

40. Flexible Two-Wire System.—For a local installation the three-wire system is not a good choice, as two dynamos must be constantly running; but when there is a three-wire city supply available, a combination wiring for

the two systems may be put in, the private plant or the city mains being used as may be convenient. This arrangement is known as the **flexible two-wire system,** and is almost identical with the three-wire system, the only difference being that the neutral wire *N*, Fig. 30, is made double the size, in sectional area, of each of the outer wires. When used on the two-wire multiple-arc system, the connection to

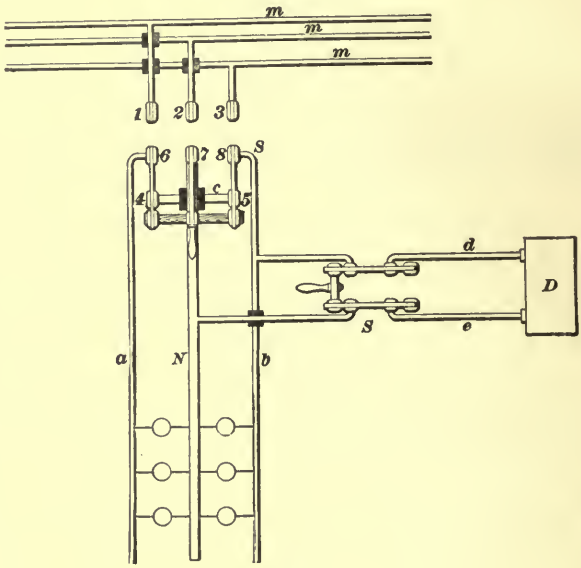


FIG. 30.

the street mains *m*, *m*, *m* is broken, and the two outer leads are joined together and to one terminal of the dynamo in the building, and the middle wire to the other terminal. This may be accomplished by means of a special switch *S*, as shown in the figure. The upper contact-blocks *1*, *2*, *3* are connected to the street mains, and the lower two, *4* and *5*, are joined together by a copper bar *c*. The several contacts *6*, *7*, *8* are connected to the three blades of the switch, which are insulated from each other. When the switch is thrown upwards, the mains *a*, *N*, *b* are put in communication

with the street mains m, m, m; when it is thrown downwards, the outer mains a, b are joined together through the circuit *6–4–5–8*; and, the other switch being closed, the leads d, e from the dynamo D supply current to the lamps throughout the whole system, the heavy wire N acting as a return path for the current passing through the two outer mains a, b.

41. There is an important consideration to be remembered as regards the E. M. F. of the dynamo. If lamps taking 110 volts are used, the E. M. F. across the mains a, b for the three-wire system will be 220 volts. If the drop of potential (Art. **14**) be 5 per cent. from street mains to lamps, there will be a loss at full load of about 11.5 volts, being 5.75 volts in each main a and b, the neutral wire taking no current. On changing over to the two-wire system, there will be the same percentage of loss in each of the mains a and b, and an equal loss in the return wire N, being a total drop of 11.5 volts. Therefore, the dynamo must furnish an E. M. F. of $110 + 11.5 = 121.5$ volts, although the pressure on each side of the three-wire system, at the street mains, is only $110 + 5.75 = 115.75$ volts. In this case, however, the neutral wire carries practically no current, the drop being confined to the outer mains.

METHODS OF WIRING.

42. Feeders and Mains.—**Feeders** are conductors supplying current to single terminal points or distributing centers, running directly from the source of current to those points without any branches or other connections throughout their length.

Mains are conductors which are tapped at many points for supply of current to branch circuits. In Fig. 31 the heavy lines $a\,b$, $c\,e$ are the mains, and $m\,n$, $r\,p$, m_1, n_1, $r_1\,p_1$ are the feeders extending from the dynamos d, d_1 to the mains. These latter are tapped at any desired points for the branch circuits l, l, l.

43. There must always be some drop in potential along the conductors, as has already been pointed out, but it is of the utmost importance that the drop from the dynamo or street mains to the lamps at any point of the system should be uniform, so that all the lamps may burn at the same

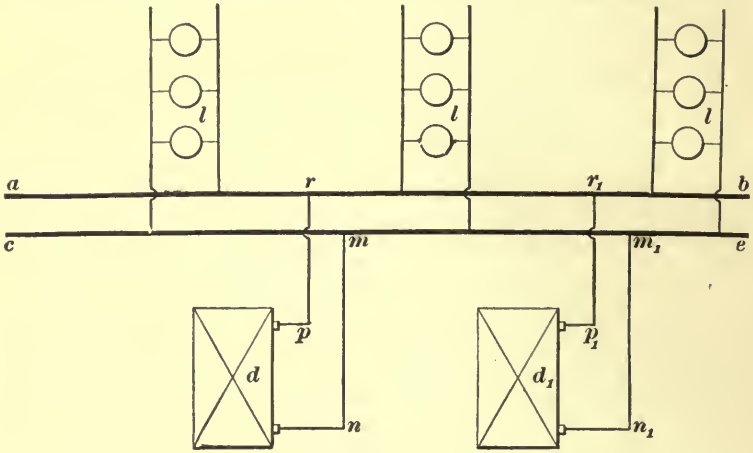


FIG. 31.

degree of brilliancy. If the drop to one set of lamps were 2 volts, and to another set 5 volts, then when the first was burning brightly, the second would be 3 volts below its required voltage, and the lamps would appear quite dim. The amount of drop usually allowed is about 5 per cent., and this is divided over the feeders and mains and branches according to their length, or as special conditions may warrant.

44. Connections for Equalizing the E. M. F.—Fig. 32 shows two methods of preserving equal E. M. F.'s at all points. At (*v*) is shown a **loop circuit,** in which the drop from the dynamo terminals to any lamp is the same. It will be seen that the length of circuit through *c–y–x–h–a* for the lamp *l* is equal to that through *c–n–z–h–a* for the lamp l_1, so that all will burn with equal brightness. A closed loop circuit is shown at (*w*), one feeder from the dynamo *d* being connected to the inner ring, and one to the outer ring. It

will be understood that this is diagrammatic only, for in practice these two circles would be of the same diameter,

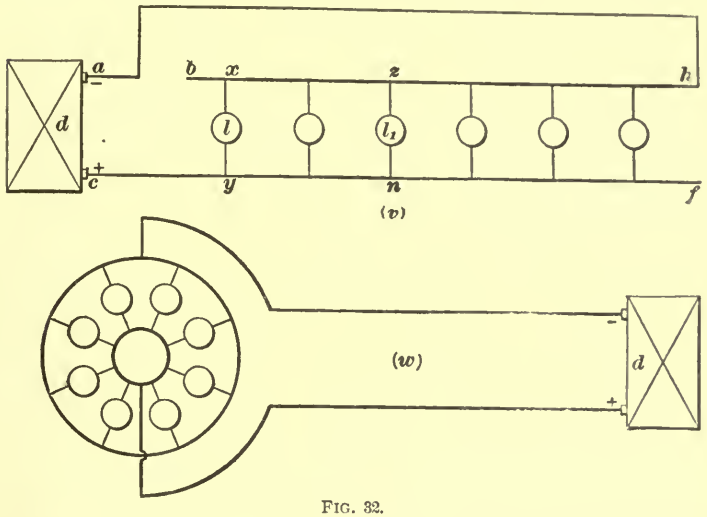


FIG. 32.

insulated from each other, of course, the lamp leads being connected on all around at the required points.

45. Tap circuits are those wires making actual connection to the lamps from the submains. There are several methods of arranging these wires, the simplest being as shown at *A*, Fig. 33. This may, however, result in the further lamps burning quite dimly, if there are a number on the circuit. A better method is *B*, which bears some resemblance to the loop system, and is a very good way of arranging the leads. A third method, shown at *C*, is like a feeder and main on a small

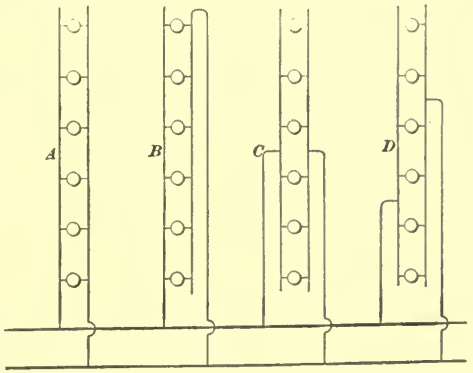


FIG. 33.

scale, and that shown at *D* is a modification which gives better distribution of pressure. The first mentioned may be used when the number of lights is small, and that marked *C* for double the number, since the connection is at the middle. In small tap circuits it is not usual to allow for any drop of potential, since the wires are short and the loss is insignificant.

46. There are, broadly, two systems of house wiring: the *tree system* and the *closet*, or *cabinet*, *system*.

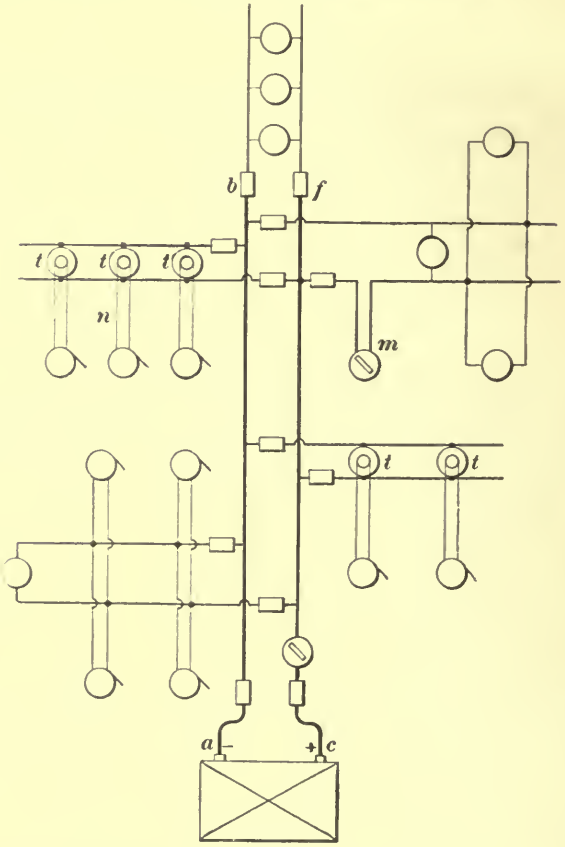


FIG. 34.

The **tree system** is illustrated in Fig. 34. The general distribution of wires is somewhat similar to the trunk and

branches of a tree, hence the name. The mains *a b*, *c f* are carried through the building, being heavier at the lower end which carries the entire current. If, however, the mains are only of moderate length, they may be of equal size throughout. In the tap circuits the rosette cut-outs *t*, *t*, etc. are similar to that shown in Fig. 15, lamps with key sockets being attached. When keyless sockets are used, a switch such as *m* is placed in some convenient position.

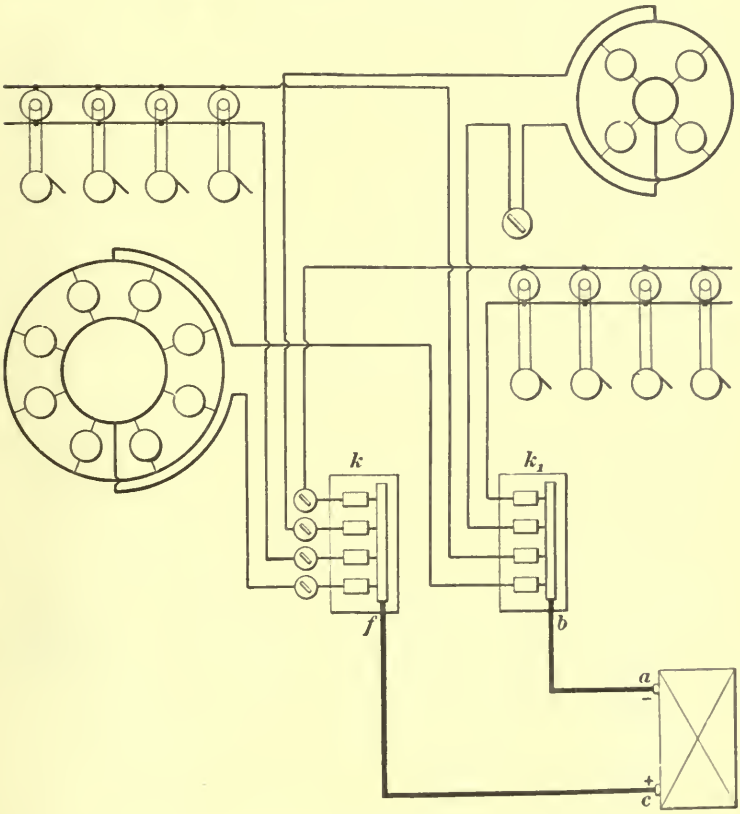


FIG. 35.

47. The **closet system**, shown in Fig. 35, is more generally used than the tree system. Separate feeders are run to various distributing centers, and from these points the

smaller, or tap, circuits start. The feeders in the diagram are *a b* and *c f*, making connection between the dynamo and the closets *k* and k_1. In these closets the wires to each group of lamps are branched off. The two distributing boards may both be arranged in one closet, unless there is a considerable number of circuits, making a double closet desirable. They are usually lined with asbestos, and painted outside with insulating paint. Cut-outs are always connected where a conductor branches off, and frequently in the leads of each lamp. On entering the closet, the leads are generally separated into two groups, one consisting of the positive, and the other of the negative, wires, in order to reduce the possibility of short circuits. The placing of switches is subject to convenience, one or more being used to control the lamps for each room, and main switches are installed for each floor of a house. One large switch is always located at the dynamo or at the point where the wires enter the building, so that the whole system may be disconnected when required.

48. The **transformer system** is sometimes used in house lighting. The **transformer** is a stationary piece of apparatus consisting of two insulated coils of wire, surrounded by a mass of iron, the whole enclosed in an iron waterproof case, Fig. 36. The insurance regulations require that the transformer be placed outside the house, and it is usually bolted to the outer wall or carried on a near-by pole. The current is supplied to one of the coils at a pressure of perhaps 2,500 volts, and the house current is taken from the terminals of the other coil, at a pressure suitable for the lamps. The first of these coils is called the **primary,** and

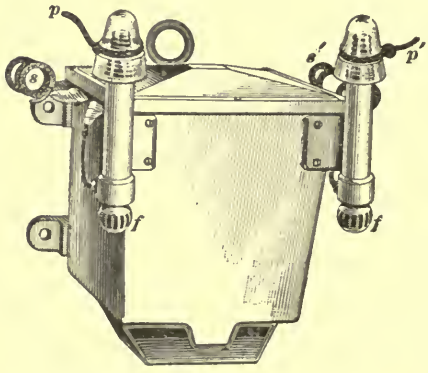


FIG. 36.

the wires are shown at p, p'; the other coil is the **secondary,** and its terminals are indicated by the letters s, s'. In this transformer, fusible cut-outs f, f are provided for the primary circuit, being inserted from the lower end of the cylindrical corner brackets on the case.

INTERIOR WIRING.

49. There are three methods of running electric-light wires, namely, *cleat work*, *molding*, and *concealed work*.

Cleat work is used in such places where appearance is of little consequence, as in factories, and is the least expensive method of running wires. **Cleats** are narrow strips of wood placed at regular intervals along the wall or ceiling, arranged to hold the wires in position, clear of each other and of neighboring objects. Such a cleat is shown in Fig. 37. It is made in two pieces, the lower *a* being a flat strip $\frac{1}{2}$ inch or more in thickness by about 1 inch in width and 4 inches long; the cap *b* has grooves across its lower surface to receive the wires, which must be separated at least $2\frac{1}{2}$ inches to conform to the requirements of the insurance companies. The cleat is secured to its support by means of screws passing through the holes *s, s*. Screw cleats, such as that illustrated in Fig. 38, may be used if desired. In this style of insulator, a porcelain split bushing *b* is put over the wire and supported

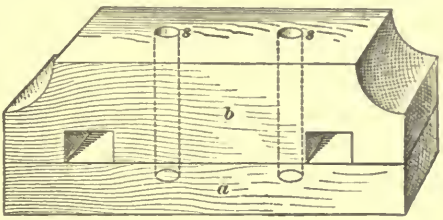


FIG. 37.

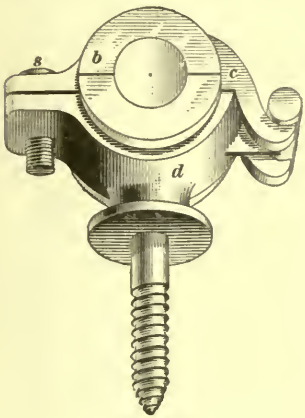


FIG. 38.

by a metal clamp in two pieces *c* and *d*, held together by a screw *s*. A wooden bushing is sometimes substituted for the porcelain, but does not provide as reliable insulation.

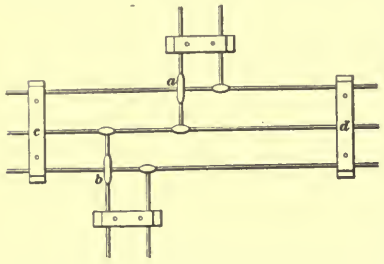


FIG. 39.

50. When a wire crosses another, and there is the full E. M. F. of the circuit between them, extra insulation is required, and a wrapping of rubber tape may be laid on, as indicated in Fig. 39 at *a* and *b*. The cleats *c* and *d* have three notches in them to receive the three main leads, and are correspondingly larger than the two-wire cleats.

51. When the wires are to pass through a wall or partition or wooden beams, they must be protected by insulating

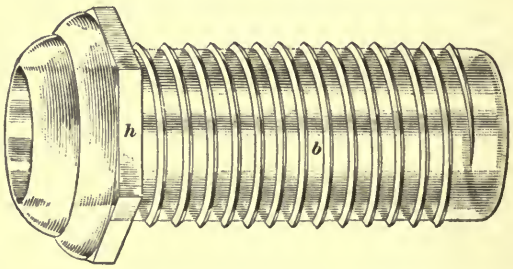


FIG. 40.

tubes of glass or porcelain, or some substance that will not burn, and so constructed that they will not pull out of place. Such a tube is shown in Fig. 40; the thread on the body *b* enables the insulator to be screwed firmly into place by means of the hexagonal head *h*, which has a shoulder like a bolt head, and may be set up tightly.

52. When the house-service wires are brought into the building direct from an overhead line, wall insulators of the

type of Fig. 41 should be used. It will be noticed that the outer end projects downwards, and the bend thus given to the wire, called a **drip loop,** will cause the rain to fall off at *a*, which would otherwise creep along the wire into the house.

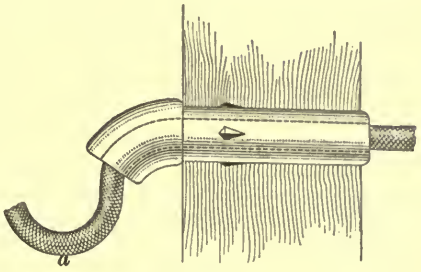


FIG. 41.

53. In breweries, dye houses, etc., the wires, being subject to dampness, must be separated at least 6 inches, and waterproof keyless sockets should be used for the lamps. In paper mills, sawmills, etc., which present extra fire risks, no switches should be used. The smallest size of wire allowed for cleat work is No. 12 B. & S.

54. Molded work is a style of wiring more ornamental than cleat work, and is generally used in houses in which no provision has been made for accommodation of the wires at the time of building. The molding is made of pine cut into lengths of about 10 feet, and consists of two parts, one of which *b*, Fig. 42, is called the *base* or *mold*, and is provided with longitudinal grooves to hold the wires, and the other part *c* is called the *capping*, which is intended to hold the wires in place and present a finished exterior. For this reason the capping is usually ornamented to correspond with the decoration of the room. The base is screwed in position first, being held by the flat-head screws *s*, *s*, and the capping is then fitted over and secured by round-head brass screws *s'*; iron screws would not look well. Particular care should be taken that these screws do not touch the wires or damage the insulation, as a fault might thereby develop which would cause trouble or even fire risk. The wires, if positive and negative, should be

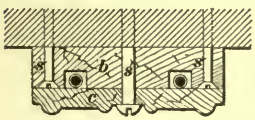


FIG. 42.

separated a distance of at least $\frac{1}{2}$ inch from each other. Molding must not be used in places where there is dampness, and should in every case have at least two coats of some waterproof paint, or be otherwise treated so as to be impervious to moisture.

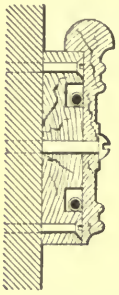


FIG. 43.

55. It is usually desirable to have molding arranged so as to be unnoticeable. It may frequently be set as a border to the wall paper, or used instead of picture molding, the hooks being attached in the ordinary manner over the edge of the capping. (See Fig. 43.) When molding is required at only one side of a room, and an unsymmetrical appearance is to be avoided, dummy molding, carrying no wires, may be employed to produce the desired effect.

56. Concealed Work.—This is the most satisfactory method of wiring a building, and consists in providing a complete network of tubing, laid beneath the plaster of the walls, between partitions and under floors, to receive the wires at any time and allow of their removal if necessary. Such a system of tubing is known as **interior conduit.** The tubing is made of papier mache, which, by treatment with a bituminous solution, is rendered waterproof and insulating. In appearance it is like Fig. 44, and is made in all sizes from $\frac{1}{4}$ inch to $1\frac{1}{4}$ inches inside diameter, in lengths of about 10 feet. Joints are made by carefully smoothing the ends of two pieces so that they will make a close butt joint with no rough edges, and threading them into a metal sleeve, which is then compressed into the tube by means of a special tool. The joint then appears as shown in Fig. 45. The conduit is also made with a sheet-brass

FIG. 44.

FIG. 45.

covering, for protection against rats and mice. Another form is that of an iron tube with an insulating coat on the inside, and screwed joints between different lengths. Wires of opposite polarity may be placed in these iron-armored conduits, but the papier-mache tubes may contain only one wire each. The tubes are secured in place by metal staples or brass clips. A staple driver should be used for the former, to prevent damage to the tubing.

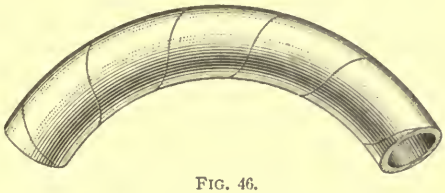


FIG. 46.

57. To insure the easy passage of the conductor, all corners are rounded, an elbow, Fig. 46, being employed for flexible wires, and a **junction box**, as shown in Fig. 47, for rigid conductors. The ends of the tubes should project well into the box through the openings *o*, *o*, etc., and a thoroughly strong soldered joint should be made between the wires, and it should be wrapped with insulating tape as a further precaution. When the tubes are all in position, a **fishing wire** is pushed through from one outlet to another, and the electric-light wire is connected to the end and pulled through.

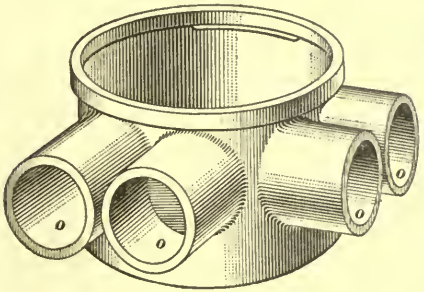


FIG. 47.

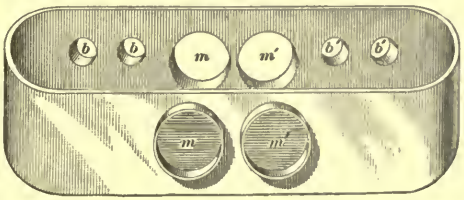


FIG. 48.

58. At the points where branch circuits start, junction boxes, such as that shown in Fig. 48, are used. At each side are openings *m*, *m*, *m'*, *m'* to take the

main conduit tubes, and smaller ones at b, b, b', b' for the branch tubes. A porcelain branch block is introduced to carry the connections and cut-outs, as in similar cases already considered.

59. Street Junction Boxes.—When connection is made between the inside wiring and the street main, a junction box such as that illustrated in Fig. 49 is employed. The

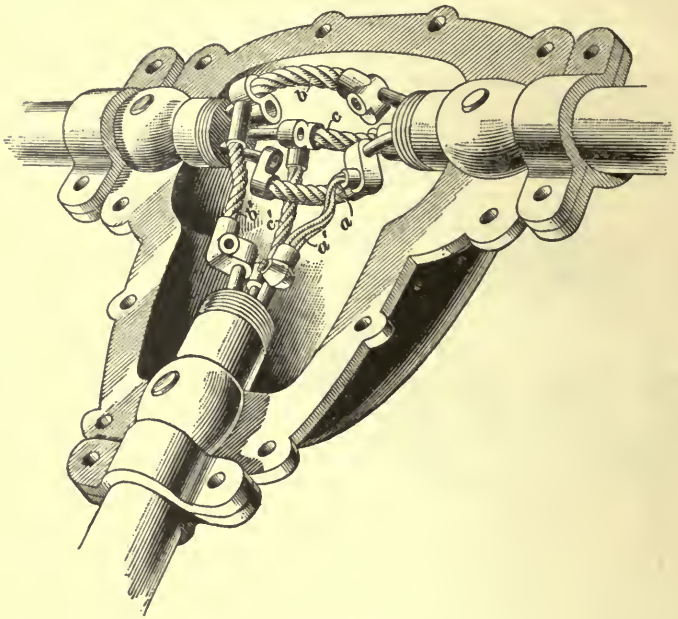


FIG. 49.

three-wire system will probably be used on account of the economy in copper so obtained. The three mains, a, b, c pass straight through the box, but from the double terminals to which they are clamped are run the house leads a', b', c'. The whole set of couplings is enclosed in a cast-iron, water-tight box fitted with a cover, and the wires for the house service are protected by an iron pipe which extends from the junction box to the cellar.

WIRING CALCULATIONS.

60. The size of wire required to supply current to any group of lamps depends on the number of lamps, each of which takes a certain average current. The following table gives the value of this current for lamps of different candlepower and with a line E. M. F. of 110 and 55 volts:

110 Volts.	Lamp.	55 Volts.
.5 Ampere.	16 Candlepower.	1 Ampere.
1.0 Ampere.	32 Candlepower.	2 Amperes.
1.5 Amperes.	50 Candlepower.	3 Amperes.
3.0 Amperes.	100 Candlepower.	6 Amperes.

Since the lamps are connected across the leads in multiple arc (Art. **3**), whether on the two-wire or the three-wire system, it is evident that the main conductors must be able to carry current for each lamp on the circuit. If the average current is .5 ampere, and there are 30 lamps on the circuit, the main conductors will have to carry $30 \times .5 = 15$ amperes.

61. In nearly all cases a very simple formula may be used in calculating the size of wire to be furnished for any particular circuit. According to Ohm's law, the loss in volts divided by the current flowing gives the resistance of the line (Art. **14**); if this result be divided by the length of the line in feet, the resistance in ohms per foot is obtained, and the size of wire corresponding to this resistance can be found directly in a wire table. Since resistances are usually given in ohms per thousand feet owing to the low resistance of copper, it will be necessary to multiply by 1,000 to find the corresponding gauge of wire.

We may express these operations in the shape of a formula as follows:

$$R_f = \frac{E}{CL}, \qquad (4.)$$

where R_f is the resistance per foot of the wire, E the drop

in volts, C the current, and L the length of the wire in feet.

We have seen, however (Art. **60**), that a 16-candlepower lamp on the usual 110-volt circuit takes .5 ampere. Then for C we may substitute the number of lamps N multiplied by the current required for one, or $N \times .5$. The total length of line L is also equal to $2\ F$, when F is the distance in feet as measured along the double line between the point of supply and the lamps. We may, therefore, write formula **4** as follows:

$$R_f = \frac{E}{.5\ N \times 2\ F} = \frac{E}{NF}. \qquad \textbf{(5.)}$$

The term NF is the number of lamps multiplied by the distance from the source of current to those lamps; in other words, this expression gives the **lamp feet.**

From the preceding we may derive the following rule:

Rule.—*In order to find the resistance per foot of the conductor to use in any 110-volt circuit with 16-candlepower lamps, divide the loss in volts, as predetermined, by the lamp feet.*

The corresponding wire may then be found from Table 1.

Example.—A group of 41 lamps, 16 candlepower, is to be set 1,500 feet from the dynamo on a 110-volt circuit. What diameter of conductor should be used when the drop is to be 5 volts?

Solution.—The number of lamps $N = 41$, the distance in feet $F = 1{,}500$, and the drop in volts $E = 5$. The lamps being of 16 candlepower, and the voltage 110, we have from formula **5**,

$$R_f = \frac{5}{41 \times 1{,}500} = .0000813 \text{ ohm per foot.}$$

$$= .0813 \text{ ohm per } 1{,}000 \text{ feet.}$$

From the wire table we find this corresponds to No. 00 B. & S. Ans.

62. When there are other lamps on the circuit than 16 candlepower, they should be allowed for in estimating the total number as follows:

For one 32 c. p. lamp count 2 of 16 c. p.
For one 50 c. p. lamp count 3 of 16 c. p.
For one 100 c. p. lamp count 6 of 16 c. p.

EXAMPLE.—An electrolier in a large hall is provided with one lamp of 100 candlepower, four of 50 candlepower, twelve of 32 candlepower, and twenty-four of 16 candlepower. What size of wire will be required for the main conductors from the closet, the distance being 300 feet, the line voltage 110, and the drop 4 volts?

SOLUTION.—The number of lamps is to be expressed in terms of 16-candlepower lamps.

1 lamp of 100 c. p. = 6 of 16 c. p.
4 lamps of 50 c. p. = 12 of 16 c. p.
12 lamps of 32 c. p. = 24 of 16 c. p.
24 lamps of 16 c. p. = 24 of 16 c. p.
Total, ... = 66 lamps = N.

The drop in volts $E = 4$, and the distance in feet $F = 300$. Then, by formula **5**, the resistance per foot of the wire,

$$R_f = \frac{4}{66 \times 300} = .000202 \text{ ohm.}$$
$$= .202 \text{ ohm per 1,000 feet.}$$

Reference to Table 1 shows this to be almost exactly No. 3 wire, which should therefore be chosen. Ans.

63. It is always necessary to compare the results obtained by these calculations with a table of carrying capacity, in order that undue heating of the conductors may be avoided. In the example just given, the current is $66 \times .5 = 33$ amperes, since each 16-candlepower lamp would take .5 ampere, and this is little more than one-half the allowable current for No. 3 wire, as shown in Table 1, so that this wire has a large margin of safety.

64. In calculating the wire for lamps on a 55-volt circuit, formula **5** is modified to read

$$R_f = \frac{E}{2\,N\,F}, \qquad (6.)$$

since the current used per lamp is doubled. The 16-candlepower lamp is taken as the standard, as before, its current now being 1 ampere, instead of .5 ampere.

EXAMPLE.—A room is provided with a cluster of 24 lamps of 16 candlepower, and 3 of 32 candlepower. The E. M. F. of the circuit is 55 volts, and the line loss from the closet is to be 3 volts, the distance being 75 feet. What size of wire should be used?

SOLUTION.—The line loss is 3 volts $= E$; the number of lamps is 24 of 16 candlepower, and 3 of 32 candlepower, equivalent to a total of $24 + 6 = 30$ of 16 candlepower $= N$; the distance is 75 feet $= F$. Then, by formula **6**, the resistance per foot

$$R_f = \frac{3}{2 \times 30 \times 75} = .00067 \text{ ohm.}$$

$$= .67 \text{ ohm per 1,000 feet.}$$

The corresponding wire is No. 8. The current in the circuit is $30 \times 1 = 30$ amperes; but, as the limiting current for this size of wire is 25 amperes, we must take the next size larger, and use No. 7. Ans.

65. In such a case as the above, we might wish to know what the resulting drop will be, since we have to use a different size of wire. This is easily obtained by a reversal of formula **6**, for a 55-volt circuit:

$$E = R_f \times 2\,NF = 2\,R_f\,NF. \qquad (7.)$$

No. 7 wire has a resistance per 1,000 feet of .519 ohm, or .000519 ohm per foot. As before, $N = 30$, and $F = 75$. Then

$E = 2 \times .000519 \times 30 \times 75 = 2.33$ volts, the required drop.

In the same manner, the drop may be found for a 110-volt circuit, when the size of wire, the number of lamps, and the distance are known, by a modification of formula **5**,

$$E = R_f NF. \qquad (8.)$$

EXAMPLE.—What will be the drop in a 110-volt circuit, in which is located a group of 15 lamps of 16 candlepower, the distance from the point of supply being 270 feet, and the wire No. 10 B. & S.?

SOLUTION.—The resistance per 1,000 feet of No. 10 wire = 1.04 ohms, or per foot = .00104 ohm $= R_f$. The number of 16-candlepower lamps is 15 $= N$, and the distance in feet is 270 $= F$. Then, by formula **8**, $E = .00104 \times 15 \times 270 = 4.2$ volts, the drop. Ans.

66. When, in calculating the wire for a lighting system, it is necessary to use a size of wire larger than that required for the given drop, the effect may be balanced by using a smaller wire than that called for in another part of the same circuit. Suppose, for instance, a total drop of 6 volts were allowed in a circuit composed of two different lines, and it was decided to provide for a drop of 2 volts in one part, and

4 volts in the other. If, then, it should be found that the wire to give 4 volts drop was too small to carry the current safely, and a larger wire had to be used, giving a drop of only $3\frac{1}{2}$ volts, the second wire could be designed to allow a drop of $2\frac{1}{2}$ instead of 2 volts, provided, of course, that the safe carrying capacity were not exceeded.

When the calculations call for a wire smaller than No. 14, it should not be used, as this size is the smallest allowed by the underwriters for interior wiring.

67. In calculating the wire for a loop circuit such as shown in Fig. 50, the total length of conductor is evidently $(4\times75)+(4\times20) = 380$ feet, but the actual length traversed

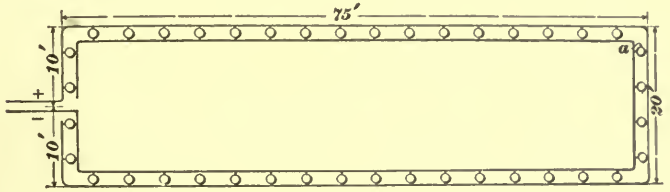


FIG. 50.

by the current for any one lamp, such as *a*, is $10+75+20+75+10 = 190$ feet for the double distance. If there are 40 lamps on the loop, the lamp feet (Art. **61**) will be 40 times one-half this double distance, or $40\times95 = 3{,}800$ lamp feet, giving the same result as if the lamps were all bunched at the further end.

Rule.—*In determining the size of wire for a loop circuit, multiply the number of lamps by one-half the distance, in feet, around the loop. This will give the lamp feet N F, to be used in the formulas already given.*

EXAMPLE.—What size of wire is required for a loop circuit similar to Fig. 50, having 26 lamps, 110-volt, 16-candlepower, the length of the room being 80 feet, and the width 30 feet? Allow for 3 volts drop.

SOLUTION.—The total length of circuit through any one lamp is $(2\times80)+(2\times30) = 220$ feet, and the single distance is $\frac{220}{2} = 110$ feet

$= F$. The number of lamps is $26 = N$, and the allowable drop is 3 volts $= E$. Then, since 16-candlepower lamps are installed, and the E. M. F. of the circuit is 110 volts, the resistance per foot of the conductor will be, by formula **5**,

$$R_f = \frac{3}{26 \times 110} = .00105 \text{ ohm.}$$

$$= 1.05 \text{ ohms per } 1{,}000 \text{ feet.}$$

By reference to the wire table, it will be seen that this corresponds almost exactly to No. 10 wire. The current is $26 \times .5 = 13$ amperes, which is within the safe limit, and No. 10 wire will be used. Ans.

68. Heavy Conductors.—It frequently happens that a very large wire is necessary for a feeder, and the resistance is not given in the wire tables, so that the formulas already considered will not apply. In this case, the area of the wire in circular mils (Art. 8) is calculated by the following formula, for 110-volt circuits:

$$A = \frac{10.8\,N\,F}{E}, \qquad (9.)$$

in which N, F, and E have the same significance as in the preceding formulas.

EXAMPLE.—The feeders from the switchboard to the distributing center in a certain installation are 160 feet in length, and carry the current for six hundred 16-candlepower 110-volt lamps, a drop of 2.5 volts being allowed. What is the size of the wire?

SOLUTION.—The number of lamps is $600 = N$; the distance is 160 feet $= F$; and the drop is 2.5 volts $= E$. Then, by formula **9**, the area of the wire in circular mils

$$A = \frac{10.8 \times 600 \times 160}{2.5} = 414{,}720 \text{ circ. mils.} \quad \text{Ans.}$$

69. To check the results obtained from formula **9**, it is necessary to find the safe carrying capacity of the wire. For this purpose reference may be made to the accompanying table, which gives the carrying capacity of concealed cables, the difference between successive sizes being 100,000 circular mils. Any intermediate size will have proportional capacity.

TABLE 2.

CURRENT CAPACITY OF CABLES.

Area in Circular Mils.	Current in Amperes.	Area in Circular Mils.	Current in Amperes.
200,000	200	1,100,000	673
300,000	272	1,200,000	715
400,000	336	1,300,000	756
500,000	393	1,400,000	796
600,000	445	1,500,000	835
700,000	494	1,600,000	873
800,000	541	1,700,000	910
900,000	586	1,800,000	946
1,000,000	630	1,900,000	981
		2,000,000	1,015

In the example of Art. **68,** the current required by 600 lamps of 16 candlepower and 110 volts is $600 \times .5 = 300$ amperes. Referring to Table 2, it is seen that a wire of the calculated area will carry over 336 amperes; consequently, the size computed may be used.

70. In some cases, the loss in E. M. F. in a circuit is given as a certain rate per cent. It is obvious, on consideration, that this is not to be taken as referring to the voltage at the lamps, for the drop in potential is between the point of supply and the lamps, and the initial voltage is therefore higher than at the lamp terminals. In order, then, to ascertain the actual drop in the feeders or conducting wires, the initial E. M. F. must be determined and the lamp E. M. F. subtracted therefrom.

Rule.—*To find the drop in potential in a wiring system when the percentage of loss is given and the E. M. F. at the lamp terminals is known, multiply the lamp E. M. F. by 100 and divide by 100 minus the rate per cent. of loss. The quotient will give the initial E. M. F., from which is subtracted*

the E. M. F. at the lamp terminals, the remainder being the actual drop in volts.

This may also be expressed in algebraic form:

$$V' = \frac{100\,V}{100 - p}; \qquad \textbf{(10.)}$$

$$E = V' - V, \qquad \textbf{(11.)}$$

where V' is the initial voltage, V the voltage at the lamp terminals, E the drop in volts, and p the rate per cent. of loss.

EXAMPLE.—What will be the actual drop in voltage on a 110-volt circuit when a 3 per cent. loss is allowed for?

SOLUTION.—The E. M. F. at the lamp terminals is 110 volts $= V$, and the per cent. loss is $3 = p$. Then, by formula **10**, the initial voltage $V' = \frac{100 \times 110}{100 - 3} = 113.4$, and by formula **11**, the drop in voltage $E = 113.4 - 110 = 3.4$ volts. Ans.

71. Size of Conductors for Three-Wire System.— The method followed in calculating the size of conductors for the three-wire system is based on the same laws as for the two-wire system. When the two sides of the three-wire system are balanced, with no current in the neutral wire, the E. M. F. of the circuit is double that of a two-wire system, and since the current for one lamp also passes through another lamp in series, the total current required is only one-half of that necessary for the same number of lamps on the two-wire system. For an equal percentage drop of potential, therefore, the size of wire need be only one-fourth of that necessary in the two-wire system. If, however, the drop is to remain the same in each case, the size of wire in the three-wire system will be one-half that required for the two-wire system; for, although the resistance of the conductor for the three-wire system would thereby be doubled, the current is of only one-half the value, so that in the one case $E = C\,R$, and in the other case $E = \frac{1}{2}\,C \times 2\,R$, which values are identical.

For the three-wire system, therefore,

$$R_f = \frac{2E}{NF} \qquad (12.)$$

The resistance per foot of the conductor in a 110–220 volt three-wire system is equal to twice the drop in volts divided by the lamp feet.

For large conductors, the area in circular mils

$$A = \frac{10.8\ NF}{2E} = \frac{5.4\ NF}{E}. \qquad (13.)$$

Rule.—*In determining the safe carrying capacity of conductors for the three-wire system, remember that, with the same number and kind of lamps, the conductor carries only one-half the current of a conductor installed on the multiple-arc system.*

EXAMPLE.—What size of conductor should be used with the three-wire system with 5 per cent. loss, when 52 lamps of 16 candlepower, 110 volts, are 540 feet from the dynamo?

SOLUTION.—According to formula **10**, the initial voltage is

$$V' = \frac{100 \times 110}{95} = 115.8 \text{ volts},$$

and the drop is, by formula **11**, $E = 115.8 - 110 = 5.8$ volts. The lamp feet $= 52 \times 540 = 28{,}080 = NF$. Then, by formula **12**, the resistance per foot of the wire will be

$$R_f = \frac{2 \times 5.8}{28{,}080} = .000413 \text{ ohm.}$$

$$= .413 \text{ ohm per } 1{,}000 \text{ feet.}$$

By reference to Table 1, it will be seen that this corresponds to No. 6 wire. The current to be carried is one-half of that taken by the same number of lamps on a 110-volt two-wire circuit, or $\frac{52 \times .5}{2} = 13$ amperes, and since the wire may carry 35 amperes, it is safe. Ans.

72. Amount of Copper in Three-Wire System.—When the three-wire system is adopted in place of the two-wire system, the total E. M. F. is doubled, as we have seen, and the current is reduced by one-half. But the same amount of energy is delivered, and the drop will be the same if the conductor area is decreased in proportion to the decrease of current. Then, since the third, or neutral, wire

is usually made equal to the outer wires, the total amount of copper is reduced by one-fourth. When the *percentage* loss is the same, however, the outer wires may be in cross-section only one-fourth that of the conductors necessary for the two-wire system. But an additional conductor, the neutral wire, of the same cross-section, must be supplied, having, however, only one-half the length of the total circuit, or one-eighth the metal of the multiple-arc system.

The total metal of the three-wire system is, therefore, $\frac{1}{4}+\frac{1}{8}=\frac{3}{8}$ of the metal required in a multiple-arc system for the same number and kind of lamps, and for an equal percentage drop of potential.

The neutral wire could be made considerably smaller than the outside conductors, because it normally carries only a small fraction of the current. However, for practical reasons, it is usually made of the same size as the other conductors.

73. Arrangement of Circuits.—A group of different methods of wiring for the two-wire system is shown in Fig. 51. It will be noticed that the closet *A* is so placed that

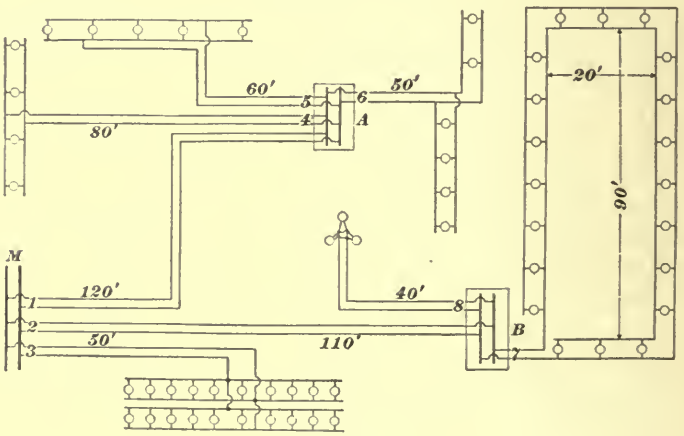


FIG. 51.

the lamp feet of the various branch circuits are approximately equal, so that the drop will be uniform in each.

From the foregoing directions it will be easy to follow out the calculations for the wiring, as embodied in the example below.

EXAMPLE.—A floor of a building is to be fitted with incandescent lamps as indicated in Fig. 51. The mains enter at M; a drop of 2.5 volts is allowed between this point and the lamps; on each circuit the length in feet is marked, this being the single distance. The lamps are 110-volt, 16-candlepower. Determine the size of feeders and branches.

SOLUTION.—Feeder No. *1* carries current for the lamps on circuits *4*, *5*, *6*, having a total of 15 lamps. The distance from the main to the closet A is 120 feet, and the lamp feet $= 15 \times 120 = 1{,}800 = NF$. The total drop allowed is 2.5 volts, of which we will use here, say, 1.5 volts $= E$. Then, by formula **5**, the resistance per foot of the wire

$$R_f = \frac{1.5}{1{,}800} = .000833 \text{ ohm, or } .833 \text{ ohm per } 1{,}000 \text{ feet.}$$

The nearest size of wire is No. 9. The current passing through the conductor is $15 \times .5 = 7.5$ amperes, which is much below the underwriters' limit, and is safe.

Subfeeder No. *4* carries current for 4 lamps a distance of 80 feet, and the lamp feet $= 320 = NF$. The drop in voltage will be the difference between the total drop allowed and that taken for the feeder in series with this subfeeder; then $2.5 - 1.5 = 1$ volt $= E$. The resistance per foot of the wire will be

$$R_f = \frac{1}{320} = .003125 \text{ ohm, or } 3.125 \text{ ohms per } 1{,}000 \text{ feet.}$$

This is smaller than No. 14, but we must use No. 14, as it is the smallest allowed (Art. **66**). The current is only $4 \times .5 = 2$ amperes, and No. 14 will carry 10 amperes, and is therefore safe.

Subfeeder No. *5* carries current for 5 lamps a distance of 60 feet, and the lamp feet $NF = 300$. The drop is the same as for circuit *4*, and $E = 1$. Then the resistance per foot of the wire

$$R_f = \frac{1}{300} = .00333 \text{ ohm, or } 3.33 \text{ ohms per } 1{,}000 \text{ feet.}$$

The nearest wire is again No. 14, and the current is $5 \times .5 = 2.5$ amperes.

Subfeeder No. *6* supplies current to 6 lamps, and the distance being 50 feet, $NF = 300$. The drop is 1 volt, and the resistance per foot

$$R_f = \frac{1}{300} = .00333,$$

the same wire, No. 14, being used here also. The current is $6 \times .5 = 3$ amperes.

Feeder No. *2* is 110 feet in length, and supplies current to 23 lamps. Then $NF = 23 \times 110 = 2{,}530$. If we allow a drop of 1.5 volts here, we shall have only 1 volt to allow in circuit 7. But circuit 7 contains actually double the length of wire, and it would be a better plan, therefore, to allow 1.5 volts here, and 1 volt in circuit *2*. Then, the wire for circuit *2* has a resistance per foot

$$R_f = \frac{1}{2{,}530} = .000395 \text{ ohm, or } .395 \text{ ohm per } 1{,}000 \text{ feet,}$$

which is between Nos. 5 and 6, either of which will carry the current safely. We regulate our choice by the result of the subsequent calculation on circuit 7.

Subfeeder No. 7 carries current for 20 lamps, arranged in a loop. We have seen (Art. **67**) that the distance used in calculation is $90 + 20 = 110$ feet $= F$, then the lamp feet $NF = 20 \times 110 = 2{,}200$, and the drop in volts is $1.5 = E$. Then the resistance per foot of the conductor

$$R_f = \frac{1.5}{2{,}200} = .000682 \text{ ohm,}$$

or, the resistance per 1,000 feet is .682 ohm, corresponding to a size between Nos. 8 and 9, but nearer No. 8. If we use the larger wire here, No. 8, we should use the smaller of the two in the case of the feeder to this closet, No. *2*, which we find should be between Nos. 5 and 6. Therefore, we select No. 6 wire for circuit No. *2*. For circuit 7, No. 8 wire is safe, the current being 10 amperes.

Subfeeder No. *8* runs to an electrolier with only 3 lights, the distance being 40 feet. The drop in this line should be $2.5 - 1 = 1.5$ volts. The resistance per foot of the wire will then be

$$R_f = \frac{1.5}{120} = .0125 \text{ ohm, or } 12.5 \text{ ohms per } 1{,}000 \text{ feet.}$$

This wire will be much too small to use, and we must take No. 14, although these three lamps will run brighter than the others. We may find the drop from formula 8: $E = .00263 \times 120 = .3156$ volt, instead of 1.5, so that the lamps will have 1.18 volts excess of pressure. This, however, will not injure them.

Feeder No. *3* carries the current for 20 lamps a distance of 50 feet. The drop is 2.5 volts, and the lamp feet $= 1{,}000 = NF$. The resistance per foot of the required conductor

$$R_f = \frac{2.5}{1{,}000} = .0025 \text{ ohm, or } 2.5 \text{ ohms per } 1{,}000 \text{ feet.}$$

No. 14 wire is sufficiently near the size to use, and will carry the current, 10 amperes, safely. Ans.

74. Wiring in Large Buildings.—For a large building, separate circuits may be run to the top floor up two or more

vertical corners. One of these circuits is shown in Fig. 52. The terminal board of the dynamo is shown at *s*, corresponding to the junction box in a public supply system, and *a b c* represents one set of feeders, which is connected to central points on the subfeeders *e f*, these again being connected to the mains *m n* at such points as will insure the best distribution of current. Tap circuits are provided for the lamps on the several floors, cut-outs being placed at all branches.

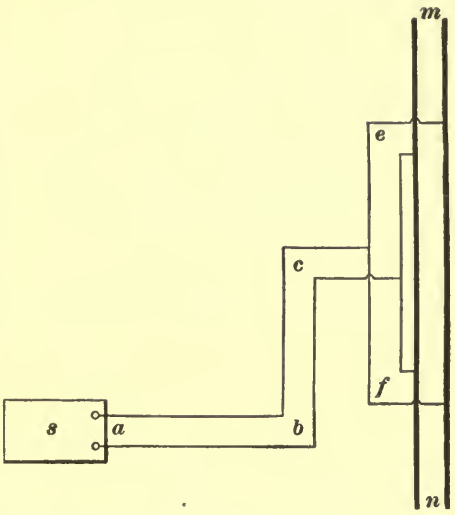


FIG. 52.

In calculating the size of the feeders, the proportionate number of lamps for each one is considered as determining the current it carries; for instance, if there are two feeders at opposite corners, each may be regarded as supplying current to one-half the lamps on each floor, although the lamps may be connected to a common set of mains.

For the three-wire system, three wires for each set of feeders or mains are carried throughout, except in the small tap circuits.

EXAMPLES FOR PRACTICE.

1. A group of thirty-three 110-volt 16-candlepower lamps is located 325 feet from the closet. What size feeder will be required, a drop of $2\frac{1}{4}$ volts being allowed? Ans. No. 3 B. & S.

2. A 6-light electrolier is set up at a distance of 35 feet from the mains. There are three lamps of 16 candlepower, two of 32 candlepower, and one of 50 candlepower, the circuit being 55 volts. With a drop of $1\frac{1}{2}$ volts, what size wire should be used? Ans. No. 13 B. & S.

3. What would be the drop in the circuit mentioned above, if No. 12 wire were substituted for No. 13? Ans. 1.16 volts.

4. A hall 30 feet wide by 95 feet long is provided with seventy-five 16-candlepower 110-volt lamps, the wiring being arranged in the form of a loop, and the lamps mounted on the walls. Allowing a drop of 2 volts, what size wire should be used? Ans. No. 3 B. & S.

5. What size conductor will be required to carry the current for four hundred and fifty-two 110-volt 16-candlepower lamps at a distance of 374 feet, the allowable drop being 2 per cent.?
Ans. 815,052 circ. mils area.

6. On a three-wire system there are to be installed sixty-two 110-volt 16-candlepower lamps at a distance of 235 feet from the closet, a drop of $1\frac{1}{2}$ volts being allowed. What size conductor will be required?
Ans. No. 3 B. & S.

TESTING.

75. When wiring is being installed, it should be frequently tested, to insure the discovery and correction of faults in the insulation, while they may be easily repaired. The method employed is to free one end of the conductor from contact with other objects, and connect the other end to one terminal of a testing instrument, the second terminal being "earthed" or "grounded" through a gas or water pipe. The resistance of such a circuit will necessarily be very high, preventing the passage of any appreciable current; but, if there be a fault at any point, a current of larger volume will flow through.

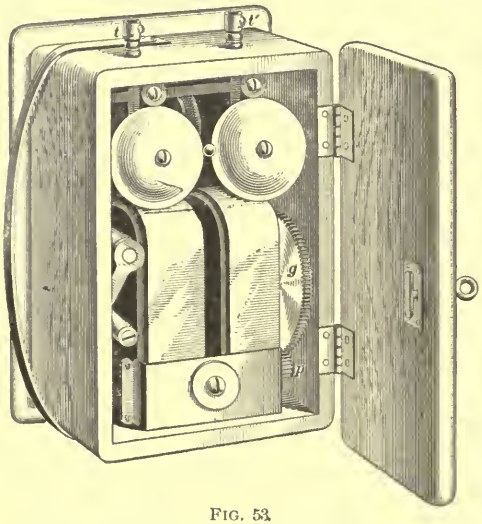


FIG. 53.

A convenient form of testing instrument is the **magneto** shown in Fig. 53. The terminals, or binding posts, to which connections are made as already described, are on the upper side at t, t'. A crank handle on the outside of the case turns the pinion p through the gear-wheel g, thereby revolving the armature of a small dynamo. If there is a fault on the line and connections are made as directed, the bell will ring on turning the crank. Care should be taken to ascertain that the gas or water pipes used for the connections are actually in communication with the street mains. The wiring will be passed by the insurance inspectors if a magneto that will ring through a resistance of 20,000 ohms shows no grounding of the circuit.

BELLWORK.

BELL CONSTRUCTION AND OPERATION.

APPARATUS FOR BELL CIRCUITS.

76. In nearly all electric appliances, particularly in those we are about to describe, the **electromagnet** is an all important feature. It was early discovered that when a current of electricity circulated through a coil of wire, magnetic poles, having the same properties of attraction and repulsion as a permanent steel magnet, were developed at each end of the coil. If a piece of iron be inserted in the coil, as in Fig. 54, the magnetic effects are much intensified; one end N of the iron core becomes a North pole, the other S a South pole, corresponding to the polarity of the coil before the introduction of the iron core. To prevent diversions of the current, the wire should be wrapped around with cotton or other insulating substance.

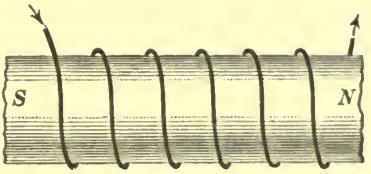


FIG. 54.

The intensity of magnetization depends on the amount of current flowing, also upon the number of turns of wire; the current, then, being measured in amperes, the magnetization is dependent upon the number of ampere-turns. Since the currents used in bell and in signal work are very small, it is necessary to wind a large number of turns around the magnet cores, thereby producing the same effect as would be obtained by a few turns of wire carrying a heavy current.

The most usual form of electromagnet for bells is that shown in Fig. 55, and is made in three parts, namely, two iron cores, such as *M*, wound with the magnetizing coils, and a straight bar of iron *b* joining the two cores. The current passes through the coils in series, and should circulate around one core in the opposite direction to that taken around the other, producing a North pole at the free end of one core, and a South pole at the free end of the other, as this condition will give the greatest attractive power for the bar of iron, called the **armature,** which is generally used in connection with this form of electromagnet.

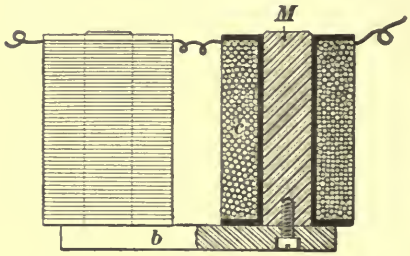


FIG. 55.

77. The principle involved in the action of the **electric bell** is an alternate attraction and release of a soft-iron armature placed in front of an electromagnet and carrying a hammer, the motion being due to intermittent currents through the wire of the electromagnet. In Fig. 56 is shown a type of skeleton bell, in which all the parts are visible. The battery wires are connected at the terminals *t*, *t'*, and the course of the current is as follows: From the terminal *t* to the adjustment screw *s*, which is tipped with platinum in order to prevent oxidation of the contact surface, through the spring *l* and the end of the armature *a* to the coils of the magnets *m*, *m'*, and out at the terminal *t'*. When no current is passing, the armature is held away from the poles of the

electromagnets, as in the position shown, but as soon as a battery is connected up and a current sent through the coils, the magnets become energized and attract the armature *a*, which swings about the pivot *p*, causing the hammer *h* to strike the bell. This movement breaks the circuit at *s* and *l*, and the iron cores being thereby demagnetized, the spring *c* draws the armature away, when the spring *l* again touches the screw *s*, completing the circuit. As long, then, as the battery current is free to flow, this vibration of the armature and hammer will continue. The tension of the release spring *c* may be changed to suit the strength of the battery, by means of the regulating screw *r*, which is provided with nuts for this purpose on each side of the supporting pillar. The bell mechanism is usually enclosed, to prevent entrance of dust or insects, which may interfere with the working of the bell by lodging on the contact points, thereby preventing the current from passing through the magnets.

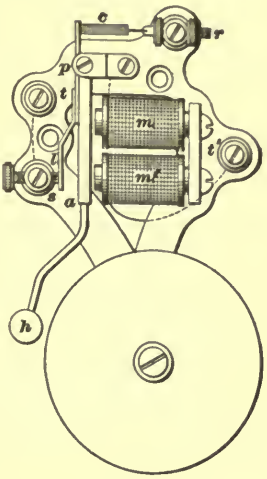


FIG. 56.

78. The bell just described is of the common vibrating class. When a bell is required to give a single stroke each time the circuit is closed, that is, for each pulsation of current, a slight difference in the connection of the ordinary bell is necessary. A wire is connected between the end of the magnet coil *m* and the terminal *t*, so that the circuit is simply from one terminal to the other through the coil. Hence, when a current passes through, the armature is attracted and held, a single stroke being given to the bell; on interrupting the current, the armature is drawn back to its normal position by the spring *c*.

79. The **buzzer,** Fig. 57, is used in places where an electric bell would be undesirable, as in small, quiet rooms

or on desks, and is constructed on the same principle as the bell, except that the armature does not carry a hammer. In the illustration, the cover *c* is removed, showing the magnet coils *m*, *m'* and the armature *a*. An adjusting screw *s* is

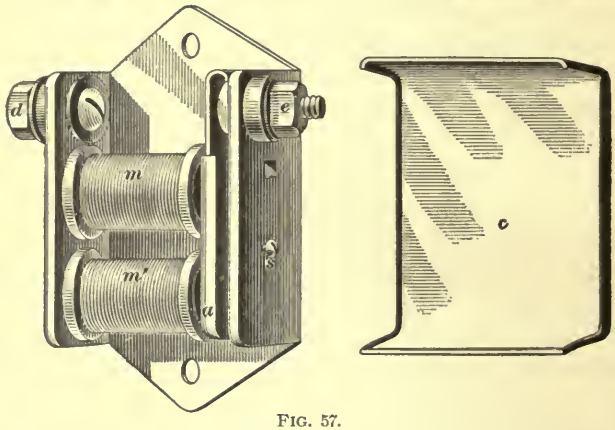


FIG. 57.

provided to regulate the stroke of the armature and the consequent intensity of sound. The wires from the push button and battery are secured at *d* and *e*, and, on closing the circuit, the rapid vibration of the armature causes a humming or buzzing sound, whence the name.

80. The circuit-closing devices used for electric bells are quite different from those used on lighting circuits, as the current and E. M. F. in the former case are very small, and there is no burning of the contacts. The ordinary switch for closing the circuit of an electric bell is called a **push button,** and is illustrated in Fig. 58. The ends of the line wire are brought up through a hole in the wooden base *a*, and held under the screws on the brass contact springs *b*, *c*. The cap *d*, in the lower view, when screwed in

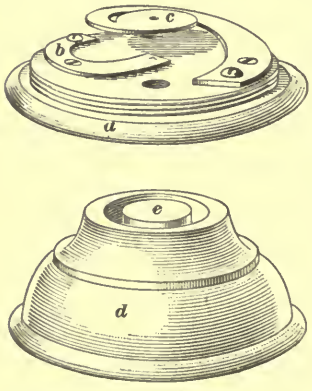


FIG. 58.

place, holds the ivory button e which, on being pressed down, forces the two springs together and completes the circuit, causing the bell to ring.

81. An electric-bell switch may easily be arranged in connection with the ordinary bell pull of a front door, in the manner shown in Fig. 59. The wires from the bell and battery are made fast by the screws s, s' to the tongues t, t', which are insulated from each other by the block r to which they are secured. The free ends press upon a rubber bushing b, and a brass washer w is drawn between the brass tongues, thereby closing the electric circuit, when the knob k is pulled.

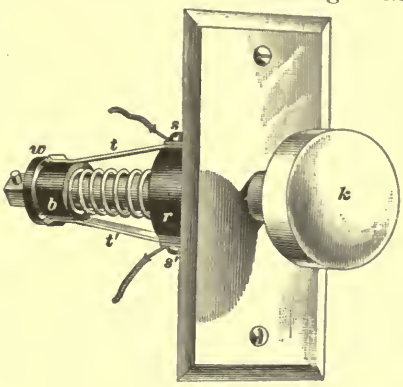


FIG. 59.

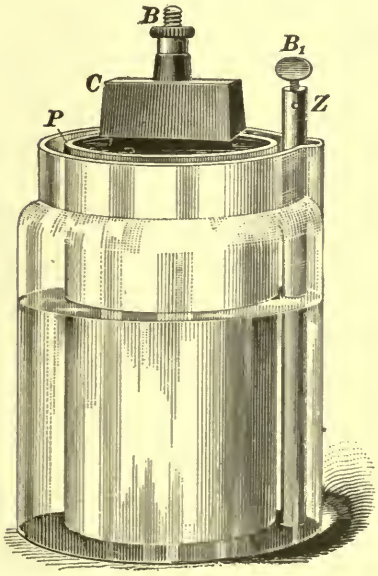


FIG. 60.

82. The battery used for electric bells is illustrated in Fig. 60. This is the Leclanché cell, and consists of a porous cup P, containing the carbon electrode C, to which a binding post B is attached; also a zinc rod Z, both being enclosed in a glass jar with a contracted top. The zinc rod is provided with a binding screw B_1 which serves as the negative terminal of the cell, B being the positive terminal. Before the battery

will furnish current, the jar must be filled to the point shown in the cut with a saturated solution of sal ammoniac, and, in connecting up, the zinc of one jar is joined by a short piece of wire to the carbon of the next. This gives a series of grouping, which is usually required in bellwork. When, after considerable use, the current from the cells becomes feeble, it will be necessary to replace the liquid, but it frequently happens that the power may be restored by the addition of a little water to make up for evaporation. The zinc will, in course of time, be consumed, and must be replaced, and the sal ammoniac may also be renewed at the same time, although it should last longer than a single zinc rod of the usual size ($\frac{3}{8}$ in. diameter). After five or six rods have been used, the material inside the porous cup will no longer act effectively, and this means, practically, a new carbon and cup, since they may be procured very cheaply. In the case of renewal of a large number of cups, they may be returned to the manufacturer, and recharged by him.

83. It is sometimes desirable to use current from a dynamo or from lighting mains to operate the bells. Of course, it will not be allowable to connect the bells directly across the line, because they would immediately be burnt out, and it is necessary to interpose sufficient resistance to cut down the current to the required amount. The resistance of a bell is usually about 20 ohms, and since it may be rung from one cell of battery, or two cells if there is a long line wire, the E. M. F. across the bell may be taken as 2 volts. The usual working current is then $\frac{2}{20} = .1$ ampere. If we denote by x the resistance to be added, the total resistance $= x+20$, which, by Ohm's law, is equal to $\frac{E}{C} = \frac{110}{.1} = 1{,}100$ ohms, and $x = 1{,}100-20 = 1{,}080$ ohms. The resistance of a 16-candlepower 110-volt lamp is, approximately, 220 ohms, and five lamps in series will be $5 \times 220 = 1{,}100$ ohms. The current will then be $\frac{110}{1{,}100+20} = .098$ ampere, which

is near enough to the required amount. The connections are shown in Fig. 61, where a, b are the 110-volt lighting mains, l the five lamps in series, and c, d the wires to the bells. If this current is found to be insufficient, one of the lamps may be cut out, when the total resistance will be $(4\times220)+20+y$, the line resistance being denoted by y. If this is 2 ohms, the total resistance will be 902 ohms, and the current $= \frac{110}{902} = .122$ ampere, corresponding to an E. M. F. across the bell of $\frac{20}{902}\times110 = 2.44$ volts. An intermediate reduction of current may be obtained by substituting a 32-candlepower lamp for one of those of 16 candlepower.

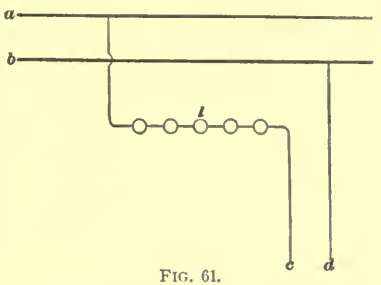


FIG. 61.

84. For special alarm purposes, it is sometimes desirable that the bell should continue to ring after the push is released. This is accomplished by the use of an **automatic drop,** which closes an extra, or shunt, circuit as soon as a

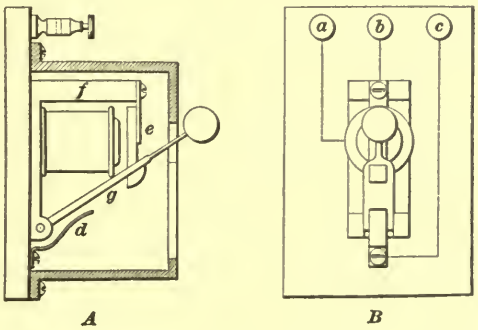


FIG. 62.

current passes along the main circuit. Fig. 62 shows two views of an automatic drop, A being a side elevation, and B a front view with the cover removed. There are three

terminals on the baseboard; those marked *a* and *b* are connected to the ends of the magnet coil, the end at *b* being also connected to the frame *f*; terminal *c* makes connection to the spring contact *d*. The bell circuit is closed first through *a*–*b* by means of the push button; the armature *e* is at once attracted, thereby releasing the gravity spring *g*, which makes contact with the spring *d*, establishing a circuit between *b* and *c* which cuts out the push button.

ARRANGEMENT OF BELL CIRCUITS.

85. A simple bell circuit is shown in Fig. 63. A battery of two Leclanché cells *c*, *c* connected in series furnishes current to the bell *b*, located at any part of the house, and the push button *p* is placed at any convenient point.

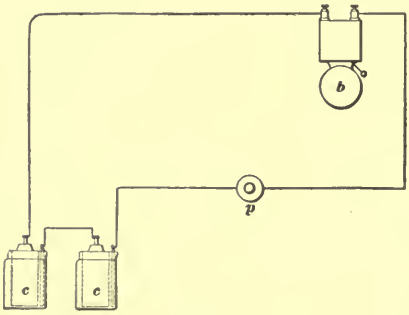


FIG. 63.

86. It is frequently necessary to ring two or more bells from one push button. This may be accomplished by one of two methods. One is to connect the bells in multiple arc across the leads, as in Fig. 64, so that each one is independent of the others, the bells *a*, *b* being on separate circuits. The battery *B* is represented in this diagram in the manner generally adopted, the fine line indicating the carbon of the cell, and the heavy line the zinc. The other method, making use of a

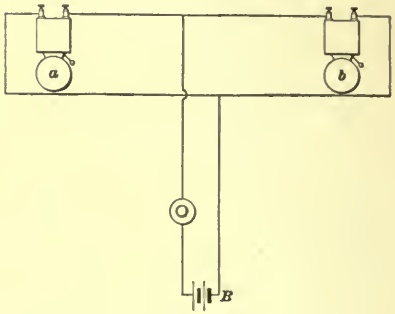


FIG. 64.

series arrangement, is shown in Fig. 65. This is often preferred to the first method, because there is usually a saving of wire in its employment, but it is necessary to change all but one of the bells to single stroke, as already explained. The reason for this is that, unless the bells were exactly similar in their adjustment, the period of vibration, or rate of swing, of the armatures would be different, and the interference would prevent satisfactory ringing of the bells. If, however, one bell is free to vibrate, and the rest are all changed to single stroke, very little adjustment to each one will be required to produce a strong, clear ring.

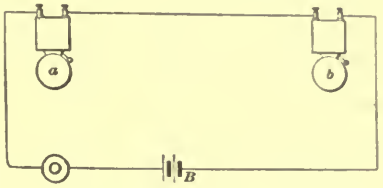


FIG. 65.

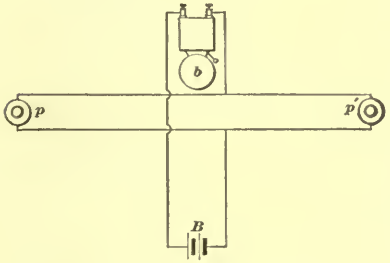


FIG. 66.

87. When it is desired to ring a bell from two different places, the simple circuit cannot be used, because there would be a break at each push button, and a current would not flow unless both buttons were pressed at once. The second button must then be in parallel to the first, as in Fig. 66, so that whichever button p or p' is pressed, the circuit through the bell b and battery B is completed.

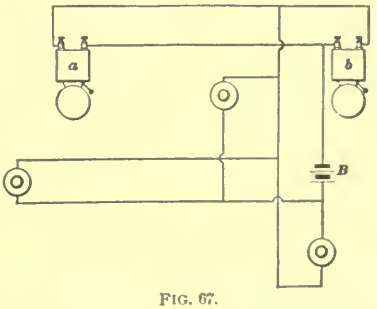


FIG. 67.

88. Figs. 67 and 68 show two arrangements of wiring for ringing two bells simultaneously from three different points. The bells a, b are connected in multiple arc (or parallel) in Fig. 67, but

they may be put in series, if desired, as in Fig. 68, provided one of them is changed to single stroke. In the case of an actual installation, it might be necessary to run the wires in some other manner than as here laid out, depending upon the construction of the building; but, from the directions already given, it should be an easy matter to devise the best arrangement. The choice between series and parallel connection of the bells will depend upon which is more economical in copper for the line wires. The wire to use will be No. 14, 16, or 18 Office Wire, according to the number of bells on the circuit.

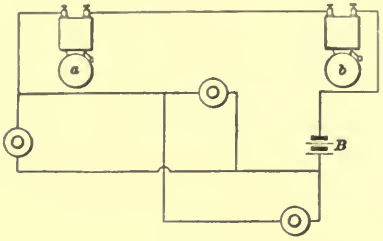


FIG. 68.

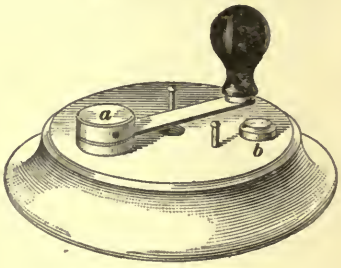


FIG. 69.

89. When two bells are arranged to ring from one push button, it is sometimes desirable to cut one of them out during some part of the day. For this purpose a small switch, Fig. 69, is used, by means of which the bell may be short circuited. The wires are run to the back of the switch, one connection being to the lever arm at *a*, the other to the contact piece *b*.

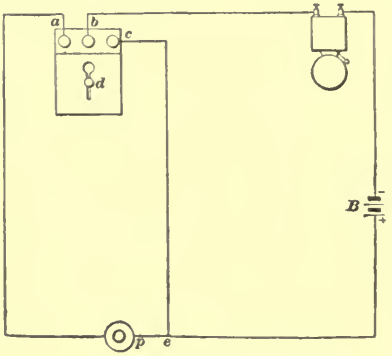


FIG. 70.

90. The connections for the automatic drop are shown in Fig. 70. The circuit obtained, on pressing the push button *p*, is from the positive pole of the battery *B* through the push to the terminal *a* of the drop, through the magnet

coils to terminal *b*, then to the negative pole of the battery by way of the bell. As soon as the drop *d* falls, the magnet coils are cut out, the current is diverted at *c* and passes by way of the new contact from terminal *c* to *b*, thence through the bell as before to the battery.

RUNNING THE WIRES.

91. The directions given in Arts. **49** to **55**, for running wires, apply to bellwork in some degree, but, in this work, the wires may be laid side by side, provided they are properly insulated. All wires should be concealed, running them under molding or behind the baseboards of rooms or hallways, when convenient. When it is necessary to cross a room, it is the best practice to run parallel with the joists under the floor; but, when the wire must run across the joists, **fishing** must be resorted to. The method employed is illustrated in Fig. 71. The joists *j* are located, and diagonal holes are bored through the floor on each side, through which the wires are drawn by means of a fishing wire, which is a steel ribbon made specially for this purpose.

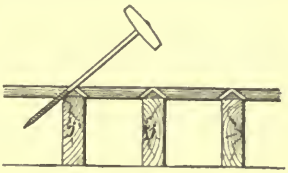


FIG. 71.

92. When a push button is to be placed on a double partition, a $\frac{3}{8}$-inch hole is drilled at that point, and a weighted line is dropped through in the intervening space. The line is then fished out at the floor level, and the wire attached. By the exercise of patience and ingenuity, it is possible to wire an old building in such a manner that there will be no trace visible of the wiring. All holes used in fishing should be filled with wooden plugs after the wires are in place.

ANNUNCIATORS.

93. When a number of push buttons is used in a call-bell system, as in the different rooms of a house or hotel, it becomes necessary to provide some means of determining

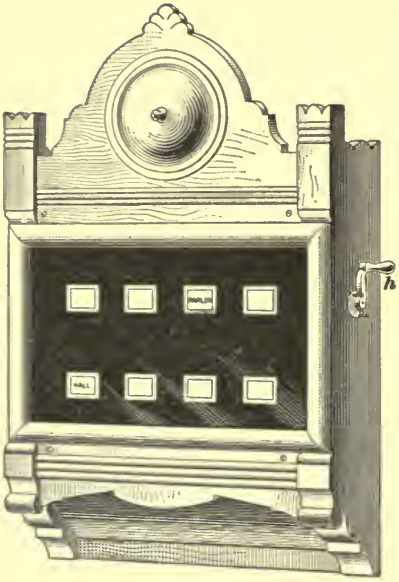


FIG. 72.

which of these buttons has been pressed when the bell rings, in order that the call may be answered. The instrument employed is called an **annunciator**; the ordinary house style is shown in Fig. 72. On the face are rows of small win-

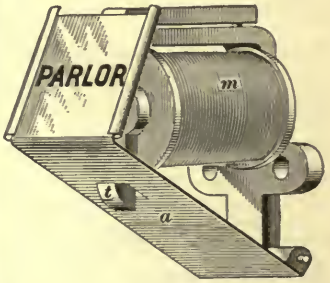


FIG. 73.

dows, before one of which an indicator appears when the bell rings, showing from which room the signal has been sent. A handle *h* at the side is intended to be used to restore the indicators to their normal position when the call is answered. A view of the indicator itself is given in Fig. 73. A hinged arm *a* carries a card, bearing the name or number of the room to which the drop is connected, and is held up, in the position shown, by a counterbalanced trip *t* in front of an electromagnet *m*. As soon as the current passes through the electromagnet, the trip is attracted and the indicator falls, being then visible from the outside through one of the openings in the front.

FIG. 74.

94. The **needle annunciator**, Fig. 74, is a style much used in hotels and for elevators. The

current, on passing through the electromagnet of an indicator, attracts a pivoted, iron armature carrying a pointer *P* on the outside dial, causing it to set in an oblique position, in which it is held by a catch until released by pressing the knob *k* below the case.

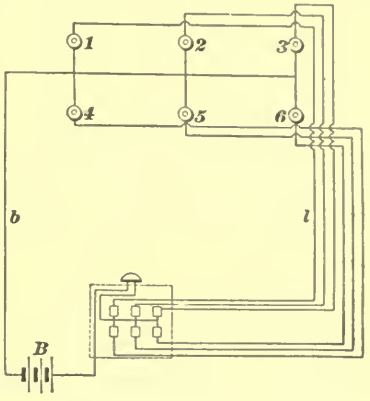


FIG. 75.

95. Wiring for Simple Annunciator.—A wiring diagram for a simple annunciator system is shown in Fig. 75. The pushes *1*, *2*, *3*, etc. are located at convenient points in the various rooms, one terminal being connected to the battery wire *b* and the other to the leading wire *l* communicating with the annunciator drop corresponding to that room. A battery of three or four Leclanché cells is placed at *B*, in any convenient location, but should not be set in a dark or inaccessible spot, or be exposed to frost.

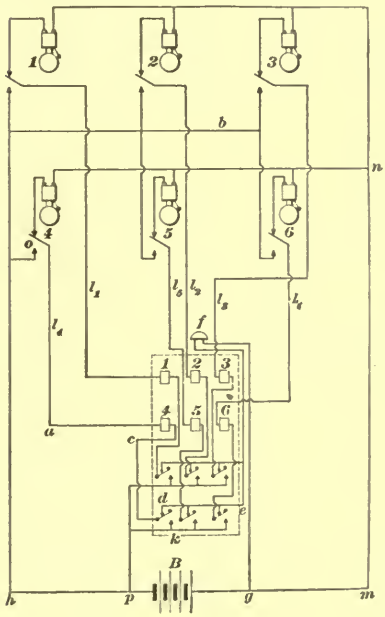


FIG. 76.

96. Wiring for Return-Call Annunciator.—In Fig. 76 is illustrated a return-call system requiring one battery wire *b*, one return wire *r*, and for each room one leading wire l_1, l_2, etc. The annunciator board is divided into two parts, the upper part having the numbered drops, and the lower the return-call pushes.

Each room is provided with a double-contact push, such as that in Fig. 77. The tongue *t* makes connection normally with the upper contact *c*, but when pressure is put on the knob *k*, the tongue is forced against the lower contact *c'*. The return-call pushes on the lower board of the annunciator are of the same description; in Fig. 76 all these pushes are shown diagrammatically, for convenience in tracing out the circuits. The closure of the circuit in any room, as, for example, No. 4, rings the office bell and releases the corresponding drop. The path of the current is then from the push *4* through *a–c–d–e–f–g–B–h–b*, and back to the lower contact of the push button. On the return signal being made from the office, the annunciator-bell circuit is broken at *d*, and, the push button in the room being released, a new circuit is formed through *k*, as follows: from the battery *B* through *g–m–r–n–o–a–c–k–p* to the battery, the room bell being in this circuit.

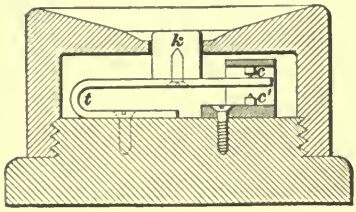


FIG. 77.

97. In installing annunciator systems, it is usual to run the battery wire, which is No. 14 or 16 annunciator wire, through the building at some central portion. If there are many rooms, it will be advisable to splice on a length of No. 18 wire to extend from the push in each room to the battery wire. The connection from the other side of the push button to the annunciator, that is, the leading wire, should be No. 18. For the return-call system, a battery of four or five Leclanché cells is required.

All wires used in annunciator service should have distinguishing colors to prevent confusion. The battery wire may be blue, the return wire red, and the leading wires white. This arrangement will greatly simplify the connections, and reduce the liability of mistake.

98. Wiring for Elevator Annunciator.—The wiring for an elevator annunciator is not materially different from that used in the simple annunciator described in Art. **95.** A single No. 14 wire, *b*, Fig. 78, is connected to one pole of the battery *B* and carried all the way up the elevator shaft, where connection is made to the pushes at each floor, as shown at *1*, *2*, *3*, *4*. The wires leading to the annunciator, in the elevator *e*, are laid side by side, and are made up into a single cable *c* for convenience, each wire being independently insulated; one end of the cable is then made fast at a point *a* midway up the elevator shaft, and connections are made from the remaining terminals of the push buttons to the wires in the cable leading to the corresponding annunciator drops. The electrical circuit is completed by a return wire *r* to the battery.

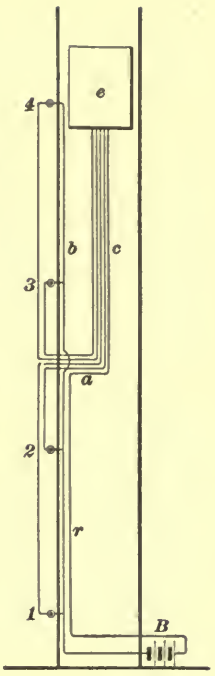


FIG. 78.

SPECIAL ELECTRIC FITTINGS.

THE ELECTRIC DOOR OPENER.

99. In apartment houses the mechanical door opener is frequently replaced to advantage by one operated electrically. A view of one of these is given in Fig. 79, which shows the position of the different parts when the door is open. The latch *a* slides horizontally, being guided at the back by the rod *r*, and is moved by the lever *l*, which is pivoted at its center *o*. A cam *c* is connected to the pin *p*, which has, at its lower end, a crank *b*, held in the position shown by means of a powerful spiral spring *s*; when the

door is closed, the cam is forced around against this spring, thereby turning the crank *b*, so that the coil spring *d* is extended. If the latch lever *l* were free to move, it would at once fly back on account of this tension, carrying the latch with it; but the lower end of the lever is held in a notch in the arm *e*, the far end of which is supported by the armature *f*, working on a pivot at the lower end, and placed in front of the poles of a double electromagnet *m*, *m*. The wires from the battery and push button are connected to the terminal *g* and the wire *w*. On closing the door, the cam is pressed inwards by a projection on the door frame, and, in turning, it moves the crank around and extends the spring, as already noted. On then closing the circuit through the electromagnet *m*, *m*, the armature *f* is attracted; the arm *e*, being no longer supported, is forced down by the pressure of the end of the lever *l* in the notch, and the lever turns around the pivot *o*, thereby drawing back the latch *a* and permitting the door to be opened. As soon as this is done (the pressure being removed from the cam), the spiral spring revolves the crank, and, compressing the spring *d*, pushes the latch lever *l* back to its original position; the arm *e* also returns to a horizontal position, by spring pressure, as soon as the lever enters the notch. The armature *f* flies back from the magnet face as soon as the current is cut off, so that the apparatus is ready for operation again after the door has been opened and closed. Since, in closing the door, the latch will not move back, an extra spring latch is provided on the door frame; this is also convenient when opening the door by hand from the inside.

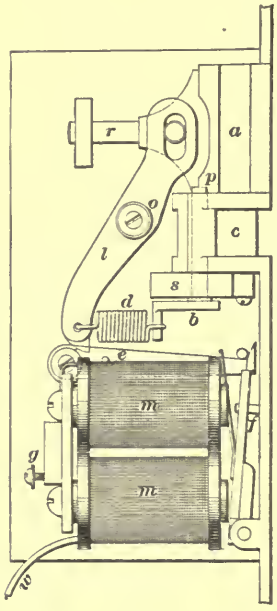


FIG. 79.

BURGLAR ALARMS.

100. Automatic switches may be placed on windows and doors, in connection with alarm bells, to indicate when entrance into a building is being forced. There are two methods of installing these alarms: the open-circuit and the closed-circuit system. The **open-circuit system** is usually employed, in which the connections are entirely similar to those of an ordinary electric-bell circuit, the automatic circuit-closing device being substituted for the push button. A window spring employed in this system is shown in Fig. 80. This is let into the window frame, the cam *c* alone projecting; when the window is raised, the cam is pressed in, revolving about the pin *p*, and makes contact with the spring *s*, which is insulated from the plate by a washer at the lower end, and is normally prevented from touching the cam by an insulating wheel *w*. The wires from the bell and battery are connected to the plate and spring respectively.

FIG. 80.

101. In the **closed-circuit system,** automatic switches of various styles are employed, but the contacts are held together when the alarm is set, and a movement of the window or door breaks this contact. Two batteries are required for this system, one

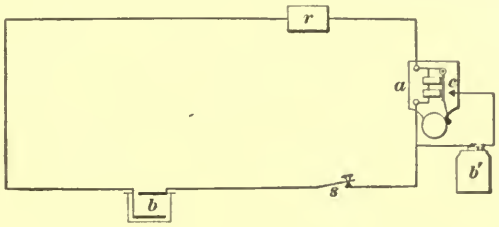


FIG. 81.

being a closed-circuit gravity battery, indicated at *b* in Fig. 81, connected in series with a resistance *r* of about 200

ohms, the magnet coils of the bell *a*, and the alarm switch *s*. The armature of the bell is thus held away from the back contact *c*. The open-circuit Leclanché battery *b'* is connected to this contact and to the far terminal of the magnet coils; the circuit is, therefore, normally open, but, as soon as the main circuit is opened, by moving the alarm switch, the spring on the armature of the bell presses it against the back contact, thereby closing the local circuit through the bell.

ELECTRIC GAS LIGHTING.

BURNERS FOR PARALLEL SYSTEM.

102. In the application of electricity to gas lighting, a spark is caused to pass between two conductors, placed near the burner, at the same time that the gas is turned on. In the **parallel system** of lighting, each burner is independent of all the others, having direct connection between the battery wire and ground. Three different styles of burner are used: the *pendant*, the *ratchet*, and the *automatic* burner.

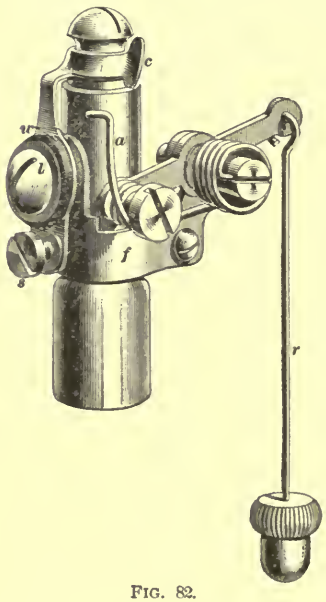


FIG. 82.

103. The **pendant burner** is shown in Fig. 82. A well insulated wire is brought to the burner and secured under the head of the screw *s*, thereby making connection to the stationary contact piece *c*, which is fastened by a screw *l* to the frame *f*, and insulated from it by washers *w*. On pulling the pendant *r* downwards, the spring *a* is drawn across *c*, and, on passing off at the upper side, the break causes a spark which, when the gas has been turned on, will ignite it.

104. The **ratchet burner** is very similar to the plain pendant, and is provided with a ratchet and pawl operated by a pendant, a downward pull turning on the gas at the same time that the spark is produced. A second pull extinguishes the gas.

105. The **automatic burner** is shown in Fig. 83, with the cover removed. Two wires must be provided, running from a double push button, one of them leading to the wire *a*, and the other to *b*. The circuit from *a* is through the left-hand magnet coil *c* to the insulated band *d*, which has a projection *e* at one side. Upon this rests a metal rod *r*, bent at the upper end, and terminating in a contact piece; at the lower end the rod is grounded by connection with the frame *f*. Each magnet coil has an armature, *g* or *g'*, with a projecting finger on the inner side. When current is sent through the magnet *c*, the armature *g* is raised and turns the gas valve *v* by striking one of the pins. At the same time the rod *r* is pushed up, thus breaking the circuit at a point where the gas is escaping, and producing a spark which will ignite it. To provide for certain action, the sparking should continue later than the instant of turning on the gas, and this is effected by the use of a spring to restore the circuit. The rod *r* is forced upwards against the spring *s*, but, when the circuit is opened at the spark gap, the spring presses the rod and armature down again, and, the circuit being thereby closed, a spark is again produced on opening. This continues

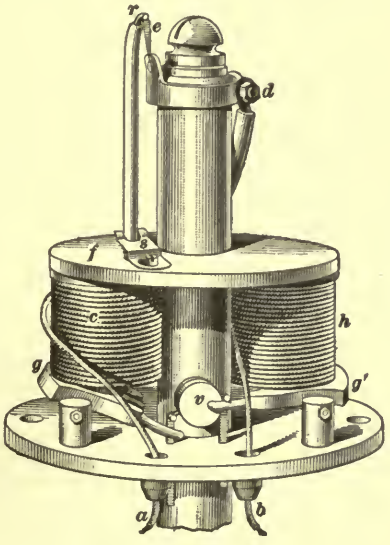


FIG. 83.

as long as the push button is pressed, the action being similar to that of an electric bell. The second coil *h* is grounded at the inner end, and, when a current is sent through, the armature *g'* is raised, turning the valve and cutting off the supply of gas.

ARRANGEMENT OF LIGHTING APPARATUS.

106. The apparatus used in electric gas lighting, on the parallel system, consists of a battery of about six cells, of a type giving a strong current, such as the Fuller Mercury Bichromate battery, and of a spark coil connected in series with it. The spark coil has a single circuit of fine wire, and its action is to produce a spark by self-induction on opening its circuit, when used in connection with the battery. The arrangement of the apparatus is shown in Fig. 84, where *k*

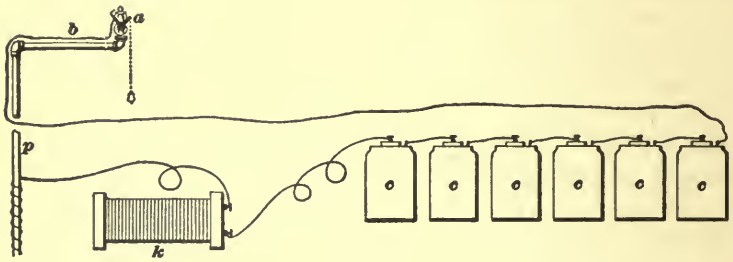


FIG. 84.

is the spark coil, connected at one side to the gas pipe *p*, and at the other side to the first cell of the series *c*, *c*, etc. From the last cell a well insulated wire is carried up to the gas bracket *b*, and connected to the tip as already described, the circuit to ground being completed through the sliding contact lever *a*. In applying the gas-lighting system to chandeliers, the wire is run in the space between the gas pipe and outer tube, and great care must be exercised in insulating at all points where sharp metal edges are passed, as the E. M. F. used is very high. Gas brackets usually have but a single pipe, and the wire should be run on the lower side, being tied on with thread and shellaced. When the shellac is dry, the thread may be removed, and the wire will

adhere to the metal. A short helix should be made wherever there is a joint, to prevent the wire from breaking as a result of frequent turning of the bracket. The wire used for this part of the construction is No. 20 or 22 B. & S. gauge, well insulated, and colored to suit the bracket. For the house circuits, No. 14 or 16 wire should be used.

107. A diagrammatic arrangement of gas-lighting apparatus is shown in Fig. 85, indicating the method of connection of the automatic and pendant burners. The spark coil S is grounded at G, and connected to the battery B at the

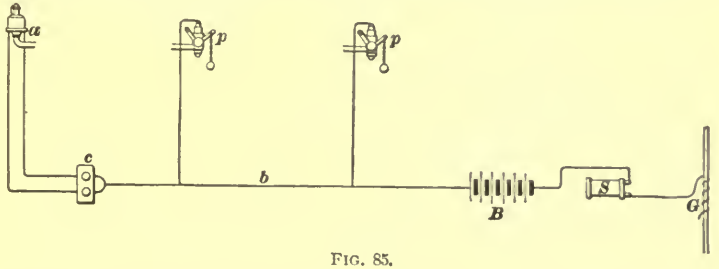


FIG. 85.

other terminal. The battery wire b runs the full length of the circuit, branches being taken to the pendants p, p, and double wires to the automatic a, the battery wire connecting with both buttons of the double push button c.

108. Since the battery is momentarily short circuited every time a spark is obtained, it would soon run down if the contacts on the burner were to remain permanently touching. To give notice of this, a **relay** (Fig. 86) may be used in series with the battery, the current entering at b and passing out at c, after circulating around the coil. The magnetic circuit is completed by an armature a, which is held back against a stop by the weight w when no current is passing. If a short circuit occurs, the armature is attracted, and the spring d is pressed against the platinum-tipped screw s, completing a local circuit, by means of the wires e, f, through a vibrating bell and one-cell battery. The current used in lighting the gas at a burner is of such short duration that the bell is not rung. A modification of this arrangement is

to provide an armature on the spark coil itself, which shall close a local alarm circuit when the battery is short circuited.

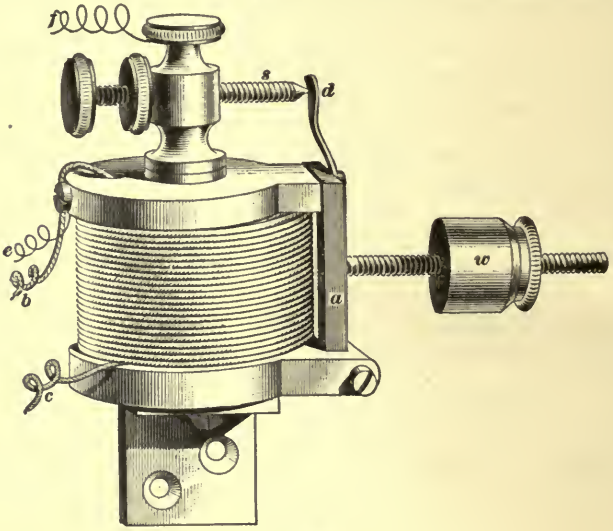


FIG. 86.

APPARATUS FOR MULTIPLE-LIGHTING SYSTEM.

109. The **multiple, or series, system** of gas lighting is used in large halls where many lights are installed in groups. A fixed spark gap is used at each burner, both of the points being insulated from each other and from the gas pipe, except the last point of a series, which is grounded. The style of burner used is shown in Fig. 87, in which *a* and *b* are the points of the spark gap. To complete the connection between consecutive burners, a fine, bare copper wire, about No. 26 gauge, is stretched across, being secured through the small holes at the lower ends of the strips *a*, *b*. The body of the burner is made of some insulating substance, and a flange of mica *m* is added to give further protection. Since one circuit may consist of a

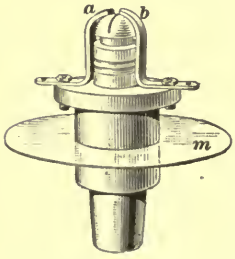


FIG. 87.

large number of burners, it will be seen that the E. M. F. must be very high to force a current across so much air space, and to insure success, the wiring must be installed with the greatest precautions. The wire should nowhere be nearer

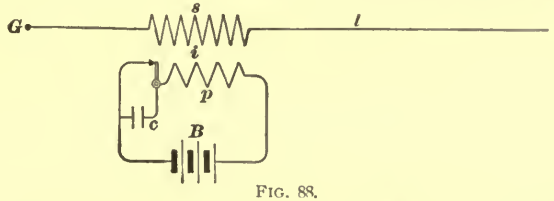


FIG. 88.

to the gas pipe than $1\frac{1}{4}$ inches; if, however, it is necessary to approach more closely, the wire should be inclosed in glass tubing.

The apparatus required for this system of gas lighting consists of an induction coil *i*, Fig. 88, operated by a battery *B*, and used with a condenser *c* across the spark gap of the primary *p*. The condenser cuts down the spark at the circuit-breaker, for this spark would be very destructive in the case of a large coil. The fine-wire secondary *s* is grounded at *G*, and the other terminal is connected to the line wire *l* passing to the burners.

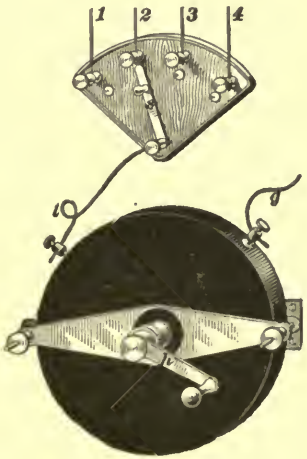


FIG. 89.

110. Frictional machines are also used in the multiple-lighting system, and generate static electricity, such as is produced when a rubber comb is passed through the hair. One form of this machine is shown in Fig. 89. One of the terminals *l* is to be connected to the switch handle *s*, and the other *g* to ground. The machine is rotated by means of the handle *h*, and the switch is moved from one contact to the next, lighting the gas on each circuit *1*, *2*, *3*, *4* in rapid succession.

A SERIES

OF

QUESTIONS AND EXAMPLES

RELATING TO THE SUBJECTS
TREATED OF IN THIS VOLUME.

It will be noticed that the questions and examples contained in the following pages are divided into sections corresponding to the sections of the text of the preceding pages, and that each section has a headline which is the same as the headline of the section to which the questions refer. No attempt should be made to answer any questions or to work any examples until the corresponding part of the text has been carefully studied.

STAIR BUILDING.

(ARTS. 1-61. SEC. 11.)

(1) (*a*) State a method of altering the stairway shown in Fig. 21. (*b*) Show how to lay out an easement curve for a stringer.

(2) (*a*) Define riser, tread, and step. (*b*) What is meant by flight and by landing? (*c*) What determines the nature of the landing?

(3) (*a*) What are balusters? (*b*) When are they fixed to the tread, and when to the stringer? (*c*) How many balusters are generally set on each tread?

(4) (*a*) What are curtail steps and bull-nose steps? (*b*) How are right and left hand stairways distinguished from each other?

(5) (*a*) What is a cylinder in a stairway? (*b*) What is a facia?

(6) Explain by diagram how to determine the exact height at which the eased rail will connect with the newel, following the method given in Fig. 34.

(7) Give a method of finding the distance between kerfs for bending wood to a required radius.

(8) (*a*) What advantage is possessed by the form of construction shown in Fig. 44? (*b*) What by that shown in Fig. 47?

(9) (*a*) How is the housing of a stringer made? (*b*) How are the steps supported between the stringers if the stairway is wide?

(10) (*a*) How should the finished work on a stairway be protected during the construction of the building? (*b*) To what are creaking noises in a stairway due?

(11) (*a*) How are the treads and risers attached to each other? (*b*) Describe the method of forming a bull-nose step.

(12) What are fliers and winders?

(13) (*a*) Why is the number of treads in each flight one less than the number of risers? (*b*) A riser has a height of 7 inches; determine the width of the tread by rules I and II.

(14) Make a sketch showing a method of describing the curves of a curtail step.

(15) (*a*) What is the proper height for a riser? (*b*) How is the exact height of a riser for a stairway determined?

(16) What advantage has the construction shown in Fig. 56?

(17) How should moldings be worked?

(18) Given a tread of 9 inches, determine the height of the riser by rule III.

(19) What are the advantages of arranging the hand rail as shown in Fig. 40?

(20) (*a*) How are portions of hallways adjoining the stairway sometimes finished? (*b*) Describe a method of fastening wainscoting so that no nails will be seen on the face.

(21) (*a*) What is meant by an *open* stringer? (*b*) What is a *close* stringer?

(22) (*a*) How are platforms supported in frame and brick walls? (*b*) Why should diagonal braces and outlooks be made of well seasoned wood?

(23) (*a*) What are the common lengths of pin balusters? (*b*) When two balusters are placed on one tread, how should they be arranged?

(24) Show by sketch and explanation how to find the center line of the rail shown in Fig. 33.

(25) (*a*) How is the front stringer formed in geometrical stairways? (*b*) In such stairways, how are the rails supported?

(26) Describe the method of scribing a wall stringer.

(27) Explain how to determine the headroom of the stairway shown in Fig. 20, without making use of the elevation.

(28) (*a*) What is a pitch board? (*b*) Where should the lower edge of the stringer be located relative to the intersection of the exposed faces of treads and risers?

(29) (*a*) What is a newel? (*b*) Where are starting and angle newels usually placed?

(30) Name the materials of which stairways are constructed, and state when each should be used.

(31) (*a*) What should be the least headroom for a stairway? (*b*) What arrangement is followed when there are winders at the bottom of the flight?

(32) (*a*) What is an open-newel stairway? (*b*) When is a stringer said to be wreathed?

(33) Make sketch of and describe the construction of a common factory stairway.

(34) What distance should exist between the center line of the rail of the flight and the facia of the landing?

(35) Show how to find the length of arc of a semicircular cylinder, following the method shown in (*d*), Fig. 23.

(36) (*a*) What is a dog-leg stairway? (*b*) What objection is there to its use?

(37) What is the primary conception of a stairway?

(38) (*a*) Name the principal points to be considered in designing a stairway. (*b*) Give the minimum widths of stairways in public and private buildings.

(39) (*a*) Mention some points to be considered in setting the hand rail. (*b*) What is a ramped hand rail, and what is its object? (*c*) When a continued hand rail is used, how may it be braced or stiffened?

(40) Show by sketch and explanation how to obtain the hand-rail easement shown in Fig. 30.

(41) (*a*) What disadvantage has the stairway shown in Fig. 49? (*b*) What is the reason for forming the risers as shown in Fig. 52?

(42) (*a*) Name two methods of construction of stairways, and state wherein they differ. (*b*) State the advantages of, and objections to, the system in which carriage timbers are cut to the angle of intersection between the treads and risers.

ORNAMENTAL IRONWORK.

(ARTS. 1–78. SEC. 12.)

(1) Describe the general construction of a small iron office.

(2) What combination is sometimes made with elevator enclosures?

(3) What characteristic renders iron of particular value as a building material?

(4) When a hand rail for a circular stair cannot be tried at the job, or on the stairs, how may it be bent to the proper curve?

(5) What distinction must be made between leafwork designed purely for ornament and leafwork designed for more utilitarian purposes?

(6) Describe two methods of casting a newel.

(7) How do iron workers and setters identify the structural pieces in setting?

(8) Why should the blows of the hammer be lighter at the commencement of welding?

(9) What are molds?

(10) Why are the sills of elevators usually either ribbed or tesselated?

(11) What consideration must receive attention in the design of posts for street and private porch lights?

(12) (*a*) What are cores? (*b*) What are core prints?

(13) How are wrought-iron scrolls usually made?

(14) In what three ways may mullions be constructed?

(15) What knowledge must be possessed in order to become a successful ironwork designer, and to advance intelligently in the work?

(16) How are the cast balusters in railings usually modeled?

(17) Why is iron used so frequently for the fronts of buildings?

(18) What is draft?

(19) Why are the thin narrow pieces secured to the guide pocket placed on each side of an elevator door guide?

(20) What is a pattern?

(21) What is cast iron?

(22) How may the width of a semicircular string be determined?

(23) What is meant by "upset"?

(24) Describe the purpose and details of a double expansion bolt.

(25) What is wrought iron?

(26) (*a*) To what interior details is ornamental ironwork particularly applicable? (*b*) What outside influence affects these interior detail designs?

(27) What is shrinkage?

(28) Describe a form of basketwork grille.

(29) What small structures are usually made of cast iron?

(30) What is a shrinkage rule?

(31) How are semicircular strings usually made?

(32) What is understood by *welded* work?

(33) Why is it necessary that cast iron should be kept nearly of equal thickness?

(34) What ingredients make wrought iron brittle?

(35) How are leaves usually made for foliage?

(36) What is casting?

(37) What considerations must be borne in mind in designing leafwork for a grille or a railing?

(38) What is understood by forged work?

(39) Of what materials are patterns usually made?

(40) Of what material are semicircular strings usually made?

(41) When bars are too thick to be twisted in grille-work, how are the intersections formed?

ROOFING.

(ARTS. 1–148. SEC. 13.)

(1) Describe the methods of constructing stone roofs.

(2) What is asbestos, and where is it found?

(3) What are snow guards used for?

(4) Describe the manner of shingling conical towers.

(5) Where is glass roofing usually employed?

(6) What is solder, and for what purpose is it used?

(7) What weight of copper should be used for gutter flashings with terra-cotta tile?

(8) Explain *single lock* and *double lock* in tin roofing.

(9) Why is copper tile so largely used?

(10) What are the joints in lead roofing called?

(11) How are the lengths of the nails used in roofing determined?

(12) State the thickness of slate usually used for roofing purposes.

(13) (*a*) Describe the pitches used in different climates. (*b*) In what way does the material used affect the pitch?

(14) In slate roofing, what course is laid double?

(15) (*a*) What are the benefits derived from using a thatched roof? (*b*) State how long such a roof will last.

(16) Describe *standing-seam* tin roofing.

(17) Why are cut slate better than square slate?

(18) What are the usual methods of laying galvanized iron?

(19) Give the weights of lead used for different parts of the roof.

(20) Give the names of the different forms of roofs.

(21) Why should the rafters be spaced the width of the metal in galvanized-iron roofing?

(22) (*a*) How many nails should be used for each sheet of tin 20 in. × 28 in. in flat-seam roofing? (*b*) When should more nails be used?

(23) Show by sketches how to brace finials on hips, ridges, and towers.

(24) Give the qualities of the different kinds of shingles used.

(25) Explain the terms *waster* and *gauge*, as applied to tin plate.

(26) Describe the methods of laying asphalt roofing.

(27) (*a*) How is copper distinguished from other metals? (*b*) What property gives it its chief value as a roofing material?

(28) What are *saddles* in roofing?

(29) Describe a squint window.

(30) (*a*) What are fluxes used for? (*b*) Name the different metals usually united by solder.

(31) What method of roofing did the Egyptians employ?

(32) Describe the characteristics of tin.

(33) How may the quality of copper be determined?

(34) What is galvanized iron?

(35) What is the proper spacing for the clips in lead roofing?

(36) Describe the terms *gauge* and *lap* in slate roofing.

(37) What advantage is gained in tinning copper?

(38) What is the greatest pitch that should be given to a roof covered with lead?

(39) Describe the *Boston hip*, and illustrate description by sketches.

(40) Explain the difference between *vitrified* and *slip-glazed* tile.

(41) What are the usual sizes of shingles?

(42) What is the most economical size of sheet to be used in tin roofing?

(43) In copper roofing, why should all vertical joints be soldered before taking the work on the roof?

(44) What tests will determine a good coating of galvanizing on iron?

(45) In what respect does lead differ from other metals?

(46) Describe wherein zinc differs from other metals.

(47) Describe the characteristics of good slate.

(48) Why should iron, copper, etc. not be used in contact with zinc?

(49) Why is machine-punched preferable to hand-punched slate?

(50) Why is felt placed under tin?

(51) What flux should be used when soldering zinc?

(52) What is the least pitch that should be given to a lead gutter?

SHEET-METAL WORK.

(ARTS. 1–83. SEC. 14.)

(1) Describe, and show by sketch if necessary, a suitable sheet-metal finish at the corner of a building whose walls are covered with corrugated sheet iron.

(2) Clearly and briefly describe, with sketch if necessary, the best method of erecting and securing in place a copper cornice 6 feet high, with a projection of 3 feet. This cornice is to be erected on top of a 16-inch brick wall. The top of the cornice will be flush with a flat roof which pitches back from the cornice.

(3) Clearly describe a "clinch" seam, as understood in cornice construction. Where is it generally used?

(4) Describe sheet-metal window sills, and explain how they are secured in place.

(5) Clearly describe, with sketch if necessary, how coping blocks over metal cornices are flashed water-tight.

(6) Describe with rough sketch (*a*) one form of eaves gutter to be put up after the shingles are on; (*b*) one form of eaves gutter to be put up before the shingles are on. State the advantages of both forms.

(7) How many 4-inch round-pipe leaders are required to take the water from a flat roof 100 feet square?

Ans. 11 pipes.

(8) Briefly describe the process of covering a ribbed dome with 18-ounce sheet copper. What should be the greatest dimensions of the sheets?

(9) What are the most important points to be considered in covering interior surfaces with ornamental sheet metal? State how the metal may be protected against rough usage.

(10) When, and in what cases, would you consider it advisable to erect sheet metal on the outer surfaces of walls?

(11) Describe stamped siding and explain its use. How should the seams be lapped? Give your reasons.

(12) What are the requirements of a good lookout for a cornice?

(13) (*a*) Distinguish between *lap* and *butt* miters in cornice work. (*b*) Describe an outside-lap miter. How are the corners strengthened?

(14) Mention one of the most important points to be considered in cutting out wooden lookouts for sheet-metal moldings, etc.

(15) Show, by sketches, two simple methods of holding sheet metal down upon large, flat slabs of stone or terra cotta.

(16) Describe a molded eaves gutter, and mention the most important points to be considered in the construction and erection of such gutters.

(17) Describe a rain-water head, and mention a few of the most important points to be considered in the construction and erection of rain-water heads.

(18) Briefly describe the process of covering a paneled dome with 18-ounce sheet copper. Give a sketch of the vertical joints between the panels.

(19) (*a*) What gauge of galvanized sheet iron is commonly used for cornices, etc.? How should galvanized-iron cornices be protected from corrosion? (*b*) What weight and kind of sheet copper is commonly used for cornices, etc.? (*c*) In

galvanized-iron cornices, what are the stamped ornamental parts made of?

(20) (*a*) Describe a plain sheet-iron wall siding. (*b*) For what purpose is it generally employed? (*c*) What is the chief objection to a plain sheet-metal siding?

(21) What are the objections to nailing sheet-metal work to brick walls?

(22) Clearly and briefly describe a butt joint in cornice work.

(23) Clearly describe, with sketch if necessary, a simple, durable sheet-metal finish in the shape of a panel course for wrought-iron beams over a store front.

(24) Clearly explain, with sketches if necessary, how sheet-metal window caps are attached to brick walls.

(25) Mention some of the most important points to be considered in the construction of sheet-metal chimney caps.

(26) Distinguish between *roof* gutters and *cornice* gutters, and explain clearly how each kind should be lined.

(27) Describe the slip-tube method of connecting box-gutter outlets to leader pipes. Explain its advantages over the common method.

(28) Describe, with sketch if necessary, a simple method of properly flashing a flagpole where it comes through a flat roof.

(29) (*a*) How can you tell the difference between hot-rolled and cold-rolled copper? What parts of sheet-metal work are they respectively adapted for? Give reasons. (*b*) What fluxes are best adapted for soldering tinned copper? (*c*) Which fluxes for plain copper?

(30) (*a*) Describe crimped sheet metal and state the benefit derived from crimping. (*b*) Distinguish between crimped and corrugated sheet metal.

(31) Clearly describe how a sheet-metal cornice may be securely erected against a brick wall (*a*) when the wall is being built; (*b*) after the wall is built.

(32) Clearly and briefly describe a lap joint in cornice work.

(33) Under what circumstances is it advisable to use cast-iron lookouts? Give your reasons.

(34) Describe a system of blocking for a three-quarter sheet-metal column, and explain with sketches how the metal is put on and where it is jointed.

(35) Clearly describe how sheet-metal balustrades are erected. What must be considered when the deck of the cornice has a pitch back towards the balustrade?

(36) Draw a section through a parapet gutter and explain the different parts. Counterflash the gutter.

(37) What provision should be made when leaders are allowed to discharge into clean-water cisterns? Give reasons.

(38) Clearly explain, or show by sketch, a good method of attaching sheet-metal crestings so that all nail heads will be covered.

(39) What provision should be made to prevent moisture from forming on the under side of a sheet-metal roof covering?

(40) (*a*) Describe corrugated sheet iron and state the class of work for which it is especially adapted. (*b*) How should the sheets be fastened against plain vertical surfaces? Describe the joints.

(41) What trouble is liable to occur when a cornice has water pockets? How can the difficulty be prevented?

(42) What weight of rivets are commonly used in (*a*) galvanized-iron cornice construction? (*b*) copper cornice construction?

(43) Distinguish between *natural* and *artificial* coloring of copperwork. How is the artificial color obtained?

(44) Briefly describe how wooden doors and shutters are made fireproof with sheet metal.

(45) Distinguish between *spun* and *pressed* balusters.

(46) Describe with sketch a good copper-lined stone corbel table gutter. State how expansion and contraction can be compensated for in a stretch of 80 feet, a rigid leader connection being made at each end.

(47) What metal is best adapted for covering domes, lanterns, etc. in the United States? Give your reasons.

(48) Mention the most important points to be considered in making detail drawings of sheet-metal finials. How should such finials be supported laterally?

(49) With what should raglet in stonework be pointed? When should this work be done?

(50) A brick foundation wall projects 3 inches out beyond the face of a corrugated sheet-iron siding. Explain, with sketch if necessary, how the siding should be finished at its base.

(51) Describe iron lookouts. Explain their use in cornice work and state how far apart they should be placed.

(52) Describe, with sketch if necessary, a cup joint as understood in cornice construction.

(53) Clearly explain how solder can be given a permanent copper color.

(54) What is the chief objection to iron fire-doors and shutters?

(55) Clearly describe with sketch how a corner pedestal of a sheet-metal balustrade may be covered, there being two paneled sides and two flat sides.

(56) (*a*) What class of leader pipes would you specify for outside leaders on a building which is located in a cold climate? Give reasons. (*b*) What should be considered regarding their fastenings?

(57) Clearly and briefly explain the best method of covering plain, smooth-surface domes with copper. What are the objections to this form of covering?

(58) (*a*) What is a weather vane? (*b*) Describe the general construction of a weather vane. (*c*) How is the movable part made and maintained sensitive to the wind?

(59) What provision must be made in sheet-copper work which has to be painted, so that the paint will hold and not change color by contact with the copper?

(60) Describe, with sketch if necessary, a good method of finishing at the eaves of a corrugated sheet-iron roof when the walls are covered with the same material.

ELECTRIC-LIGHT WIRING AND BELLWORK.

(ARTS. 1-110. SEC. 15.)

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(1) What is Ohm's law?

(2) How would you define "drop of potential"?

(3) What are the three methods of connecting incandescent lamps in circuit?

(4) What are the units employed in measurement of current, electromotive force, and resistance?

(5) What is an electromagnet?

(6) What is the distinguishing feature of the closed-circuit burglar-alarm system?

(7) A group of 30 lamps, 16 candlepower, 110 volts, is located 100 feet from the source of current supply. If the drop in potential is $1\frac{1}{4}$ volts, what size of wire should be used? Ans. No. 6 B. & S.

(8) What is the difference between series and parallel arrangement of conductors?

(9) If the resistance of a wire 3,540 feet long is 2,917 ohms, what is the size of the wire?

(10) What is a safety cut-out?

(11) What methods are ordinarily used in the production of electric current?

(12) What is the area in circular mils of a wire $6\frac{3}{8}$ inches in diameter? Ans. 40,640,625 circ. mils.

(13) A group of lamps is composed of 3 of 50 candlepower, 8 of 32 candlepower, and 32 of 16 candlepower, all supplied from a 110-volt circuit. What will be the size of feeders, the distance being 340 feet, and the drop 5 volts?
Ans. No. 4 B. & S.

(14) What method is employed in testing the insulation resistance of house circuits during installation?

(15) Under what circumstances are automatic drops installed on bell circuits?

(16) Explain the action of a pendant burner for electric gas lighting.

(17) A current of 13.5 amperes is to be transmitted to a bank of 110-volt lamps, distant 320 feet, with 5 per cent. loss in line. (*a*) What will be the resistance of the two conductors? (*b*) What is the resistance per foot, assuming each conductor to be 320 feet long?

Ans. { (*a*) .43 ohm.
(*b*) .00067 ohm.

(18) Under what circumstances may single-pole switches be used in a lighting system?

(19) Describe briefly the closet system of house wiring.

(20) What size of conductor is required for a 110-volt circuit, 540 feet in length from dynamo to lamps, when sixty-five 16-candlepower lamps are used and a drop in potential of 4.5 volts is allowed? Ans. No. 1 B. & S.

(21) What is the special advantage of the three-wire system?

(22) Make a rough sketch showing the different parts of an electric bell, and the path of the current through it.

(23) What apparatus is required to operate electric gas-lighting attachments on the parallel system?

(24) What will be the drop of potential in a 110-volt circuit having 45 lamps of 16 candlepower and 4 lamps of 32 candlepower, the distance from the dynamo being 165 feet, and the wire No. 6 B. & S.? Ans. 3.59 volts.

(25) What is the principle underlying the use of the loop circuit?

(26) To what classes of installation are cleat work, molding, and concealed work, respectively, best suited?

(27) It is proposed to supply current, by means of a No. 8 wire, to thirty-six 32-candlepower lamps mounted on a chandelier at a distance of 75 feet from the distributing box, the allowable loss being 3.5 volts. Will this size of wire be correct? Give reasons for your answer.

(28) What consideration should apply in deciding upon the location of the distributing boxes for inside electric-light wiring?

(29) What alteration is necessary to a vibrating bell in order to change it to one giving a single stroke?

(30) What size of wire is generally used in annunciator work (*a*) for the leading wires? (*b*) for the battery wire?

(31) What size of wire is necessary for a 110-volt loop circuit around the walls of a room 45 feet long by 38 feet broad, thirty-two 16-candlepower lamps being used, and a drop of $1\frac{1}{2}$ per cent. being allowed? Ans. No. 8 B. & S.

(32) In what class of work is the megohm used?

(33) What precautions should be taken when electric-light wires are passed through a wall or partition?

(34) A cluster of lights, consisting of ten 16-candlepower lamps and three 32-candlepower lamps, is installed on a 55-volt circuit. A line loss of 2.5 per cent. is allowed, the length of line from closet to lamps being 110 feet. What size of wire must be used? Ans. No. 6 B. & S.

(35) Explain the action of a buzzer.

(36) What arrangement may be used to give notice of a short circuit on a gas-lighting system operated by a battery?

(37) The feeders in a 110-volt lighting circuit are 135 feet in length, and supply current to two hundred and forty 16-candlepower lamps, with a drop of 2 volts. What is the size of conductor in circular mils? Ans. 174,960 circ. mils.

(38) What are the respective advantages of acid and resin as a soldering flux?

(39) What is the object of the neutral wire in the three-wire system?

(40) A feeder 225 feet long, No. 6 wire, supplies current to twenty-five 16-candlepower 55-volt lamps. Disregarding heating effect, what would be the drop of potential on the line? Ans. 4.625 volts.

(41) How would you proceed in installing a battery of two or three cells, for bellwork, if the cells are delivered to you in the original package, as shipped?

(42) In wiring for the multiple system of electric gas lighting, what special precautions must be observed?

(43) What means should be employed to take the strain off the connections of a lamp cord inside of a rosette?

(44) What will be the drop of potential in a 110-volt circuit, having 46 lamps of 16 candlepower, the conductor being No. 4 wire, and its length for the single distance 84 feet? Ans. 1 volt.

(45) If it is desired to ring bells from a lighting circuit, what arrangements must be made to secure this result?

(46) What is the distinction between a feeder and a main?

(47) A hall dome 120 feet in diameter is fitted with 40 lamps, of 50 candlepower each, spaced at equal distances apart in loop circuit. The E. M. F. of the system is 110 volts, and current is supplied at one side of the circle by feeders 85 feet long. Allowing for a drop of $1\frac{1}{4}$ volts in the

feeders, and 2.5 volts in the lamp circuit, what size of wire should be used in each case?

Ans. { No. 1 wire for the feeder.
No. 0 wire for the lamp circuit.

(48) Show by means of diagrams the methods of lamp connection in the multiple-arc, the multiple-series, and three-wire systems.

(49) What size of wire will be required for an installation on the three-wire system, having sixty-six 110-volt 16-candlepower lamps, the distance between these and the point of supply being 180 feet, and a drop of 2.5 volts being allowed?

Ans. No. 6 wire.

(50) When two or more bells are connected in series, what changes, if any, are necessary in their construction?

(51) When is it advisable to install the flexible two-wire system in a building?

(52) The feeders passing through a building are 80 feet long, and supply current to four hundred and eighty 16-candlepower 110-volt lamps. What size must these conductors be, if the drop of potential is not to exceed 1.25 per cent.?

Ans. 296,000 circ. mils.

(53) Show, by means of a diagram, a method of ringing a bell from either one of two different points.

(54) What will be the drop in voltage on a 55-volt circuit when a loss of 4.6 per cent. is allowed? Ans. 2.65 volts.

(55) Explain the object of a drip loop in house wiring.

(56) An installation on the three-wire system has eighty-four 16-candlepower 110-volt lamps on a circuit 320 feet long, a loss of 3 per cent. being allowed. What size of conductor is required? Ans. No. 4 B. & S.

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